PILOT STUDY: EFFECTS OF HUMAN PRESENCE ON GUANACO SPATIAL ECOLOGY

by
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ABSTRACT

The guanaco, or *Lama guanicoe*, plays an important role in maintaining Patagonian ecosystems: it is a main food source for apex and meso predators and its movement and grazing patterns preserve vegetation and insect biodiversity (Cheli et al. 2016, Baldi et al. 2016). Throughout South America, grazing competition with sheep and widespread hunting almost drove the guanaco to extinction (Baldi et al. 2001). In Argentina, guanaco populations have recovered to levels of "Least Concern," but they are still regarded as a pest species by ranchers and their populations are highly fragmented and vulnerable to reduced genetic diversity and local extinction (Baldi et al. 2016, Schroeder et al. 2014). It is still unclear the extent to which human activities or competition with sheep affect guanaco spatial preferences, and previous studies have generally not separated impacts due to hunting and competition. The purpose of this study is to look at whether human presence alters guanaco spatial distributions more than current research suggests in unprotected areas. I looked at the spatial patterns of guanacos at a ranch in the Patagonian province of Chubut, Argentina, using camera traps to count the presence/absence of guanacos in different areas of the property. I created two null models in ArcGIS based on expert and local knowledge and scientific literature to predict guanaco spatial patterns; and performed statistical comparisons between predicted guanaco encounter rates and observed guanaco encounter rates at each camera site. Over 90% of observed guanaco encounters occurred in the areas of the property that were farthest away from human residences, regardless of sheep presence and density, the location and quality of water, and the presence of roads or natural landscape features. Neither model adequately predicted the spatial pattern of guanaco encounters displayed by the observed results. This indicates that the parameters used to inform the models do not represent guanaco behavior at the study site, and, likely, that guanacos behave similarly in other unprotected areas of Argentina. This has important implications not only for connectivity and management of guanaco populations, but also for the broader health of the Patagonian ecosystem.

Resúmen

El guanaco, o *Lama guanicoe,* juega un rol importante en conservar el ecosistema árido y semi-árido Patagónico que es la fuente principal de alimento de los depredadores del ápice, de los mesodepredadores, de su comportamiento y de sus patrones de pastoreo que preservan la vegetación y la biodiversidad de insectos (Cheli et al. 2016, Baldi et al. 2016). La combinación de la destrucción del habitat del guanaco por la creciente competencia para el pastoreo con la oveja sumada a la cacería descontrolada del guanaco, estuvo a punto de llevar dicha especie a su extinción en toda América del Sur (Baldi et al. 2001). En Argentina, se ha logrado recuperar la población de guanacos hasta el nivel de "Menor preocupación de extinción" a pesar de que los ganaderos consideran al guanaco una plaga y la población de guanacos se ha visto fragmentada, haciéndolos vulnerables a una reducida diversidad genética y extinción local (Schroeder et al. 2014, Baldi et al. 2016). Aún no es clara la dimensión en que la actividad del hombre o la competencia con el ganado ovino por el alimento afectan las preferencias de hábitat del guanaco. En general, estudios preliminares al respecto no han clasificado si el impacto es debido a la caza descontrolada o a la competencia por el alimento. El propósito de este estudio es ver si la presencia del ser humano en áreas desprotegidas altera las preferencias de hábitat del guanaco más de lo que investigaciones actuales sugieren ocurre en dichas áreas. Para ello, observé los patrones espaciales del guanaco en una estancia ubicada en la provincia de Chubut, Argentina. Implementé el estudio con el uso de cámaras trampa ubicadas en áreas estratégicas dentro de la propiedad, para registrar la presencia/ausencia de guanacos. Basándome en los conocimientos de profesionales, de la población local y de literatura científica existente para predecir los patrones espaciales del guanaco, diseñé dos modelos nulos empleando ArcGIS que efectuaron comparaciones estadísticas entre la tasa de encuentros de guanaco ya predichos anteriormente y la tasa de encuentros de guanacos registrado en cada sitio donde se encontraban ubicadas las cámaras trampa. Más del noventa por ciento (90%) de los encuentros de guanacos observados/registrados dentro de la propiedad, ocurrieron en las zonas más alejadas de las residencias de la especie humana, sin importar la presencia o densidad del ganado ovino, la proximidad o

calidad del agua, la existencia de carreteras o características del paisaje natural. Ninguno de los dos modelos nulos utilizados predijo adecuadamente los resultados de los encuentros de los patrones espaciales del guanaco revelado por los resultados observados/registrados. Esto indica que los parámetros utilizados para proveer de información a los modelos, no representa el comportamiento del guanaco manifestado en las áreas de estudio, asimismo, muy probablemente, el comportamiento del guanaco es similar en otras áreas desprotegidas de Argentina. Dicho descubrimiento tiene implicancias importantes no solo por el efecto ocasionado en la conectividad y el manejo de la población de guanacos sino que también, por los efectos derivados en la salud del ecosistema completo de la Patagonia.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF IMAGES

LIST OF SPANISH TERMS

Estancia	a ranch, often of a large area, dedicated to rearing livestock
Gaucho	the horsemen who work with livestock in Argentina and Chile, and can refer to both workers on large *estancias* and small landowners. *Gauchos* are emblematic of Patagonian culture.
Bostadero	these collections of guanaco feces, or *bosta.* Guanaco herds will defecate in the same concentrated areas, and consistently return (30)
Relincho	guanacos emit a shrill call to either alert other members of the herd to danger or to intimidate another guanaco or smaller predators, like foxes.
Tajamar	Manmade lagoons. These are made by digging deep holes into the ground that collect rainwater.

LIST OF ABBREVIATIONS

HWL	Human Weighted Layer
NHWL	No Human Weighted Layer
LCP	Least Cost Pathway

INTRODUCTION

The loss of animal biodiversity and life due to human has impacted every ecosystem and led to the loss of millions of species. “Anthropogenic defaunation” – coined in a 2016 paper by Young et al - describes the present increase in human-caused animal extinctions (Young et al. 2016). Habitat loss and fragmentation due to urban and agricultural expansion, pollution and climate change are the largest contributors to animal species loss. Most of the world’s terrestrial vertebrate species occupy roughly 50% of their historic range (Young et al. 2016). Climate change further diminishes the amount of suitable habitat available to many species as seasonal shifts change the timing of crucial ecological processes, alter vegetational composition, and decrease available resources (Berger et al. 2015). Legal and illegal hunting and harvest often reduce already vulnerable populations, and in some cases are a greater threat to a species’ persistence than habitat loss and climate change (Young et al. 2016, Aryal et al. 2014). These conditions greatly challenge the ability of animals to maintain genetically diverse and viable populations at local, regional, and global scales. For this reason, modern vertebrate extinction rates are widely believed to be up to 100 times greater than historic rates of roughly 2 species per million per year (Young et al. 2016).

Much of the world’s biodiversity loss is concentrated in areas where poverty and economic necessity drives high rates of habitat destruction, species harvest, and competition for resources. Large herbivores are found in just 19% of their historic range (Young et al. 2016). Many large herbivorous species are found in areas where people depend on livestock rearing for subsistence. Herders in many parts of the world perceive wild ungulates in particular – animals like blue sheep, mountain goats and guanacos (the subject of this paper) – as a threat to their livelihoods and are known to kill these animals to reduce grazing competition with their livestock (Aryal et al. 2014, Karimov et al. 2018). Intensifying competition over grazing territory and water as climate change and human expansion reduce these is the primary cause of large-scale declines in ungulate species worldwide and has serious consequences for the long-term health of these ecosystems (Nabte et al. 2013). Ungulates play key roles in the regrowth and dispersal of plants species and are the primary food sources for apex and some meso predators in ecosystems like the Himalaya, the Central Asian steppe, and Patagonia (Nabte et al. 2013, Karimov et al. 2018). If left unchecked, many ungulate species could go extinct – contributing to the collapse not only of other animal species but also of the very landscape on which herders and their livestock depend.

In Argentina's Patagonian region, wild guanacos and sheep compete for resources and it is common practice for sheep ranchers to kill guanacos (Baldi et al. 2016). This caused a steep decline in guanaco numbers, and today, guanaco populations are discontinuous and fragmented throughout both Argentina and other countries in South America (Baldi et al. 2016). There is growing evidence that decreases in wild ungulate populations increase rates of predation on livestock by apex predators – which is suspected to be the case for pumas in Patagonia (Shrestha et al. 2018, Karimov et al. 2018). Overgrazing by sheep and the absence of guanacos in areas of Argentina have been linked to degrading vegetation quality and decreased vegetation biodiversity, and secondary effects on the populations of Patagonian insects (Cheli et al. 2016).

While guanacos are not as vulnerable as ungulates in other parts of the world, the fragmented nature of their population makes them susceptible to genetic bottlenecks and local extinctions (Baldi et al. 2016). Guanaco numbers have increased since their near-extinction in the mid-20th century, but the establishment of a healthy population throughout South America can only be achieved if conflict with humans is reduced. The consequences of not doing so are severe not only for the Patagonian ecosystem but also for the ranchers who depend on it.

It is important to understand the web of interactions between wild ungulates, livestock and predators and how these interactions shape conflict with humans. In this pilot study, I explore a small part of this: whether human presence causes guanacos to alter their spatial distribution more than current research suggests. I hypothesize that in unprotected areas guanacos avoid humans as they do predators, and that distance away from humans is a key factor in guanaco spatial preferences. While competition with sheep and other livestock as well as human-induced landscape changes also account for altered guanaco spatial patterns, human presence is a primary factor in shaping guanaco distribution at a fine-scale level.

BACKGROUND

1. The Guanaco

The guanaco – *Lama guanicoe*, - is the largest ungulate native to South America (Burgi et al. 2012, Baldi et al. 2016). Guanacos are descended from camelids that migrated from North America during the Pleistocene era and are the largest wild herbivore to inhabit Patagonia since the last Ice Age (San Diego Zoo Global Library, Burgi et al. 2012). Their range extends from parts of Peru, Bolivia, and Paraguay down to the southernmost areas of Argentina and Chile, including the island of Tierra del Fuego (Baldi et al. 2016). Guanacos prefer cooler climates and arid conditions, and are found in shrublands, grasslands and temperate forests at elevations ranging from sea level to over 5,000 meters (Baldi et al. 2016, Burgi et al. 2012). As it extends northwards into warmer latitudes, the guanaco's range becomes increasingly concentrated along the Andes mountains (Fig. 1).

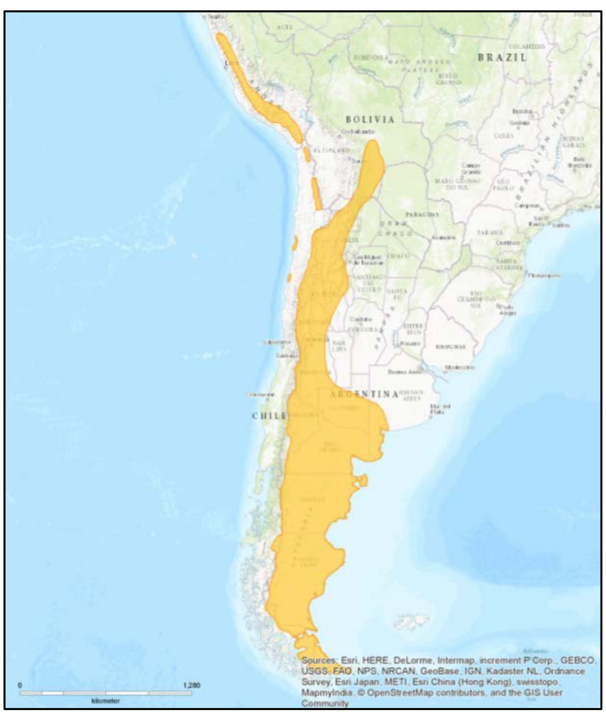


Figure 1. Range of guanacos in South America (Baldi et al. 2016)

Adult guanacos weigh between 80-120 kg and can stand about 1.1 meters tall at the shoulder. Sexual dimorphism is low in guanacos, and males are only slightly larger than females (San Diego Zoo Global Library, Baldi et al. 2016). Guanacos have a thicker light brown coat covering their backs, with a lighter layer of white hair covering their undersides and the insides of their legs (San Diego Zoo Global Library). Guanacos are not hoofed (Cheli et al. 2016, San Diego Zoo Global Library).

Instead, guanacos have soft pads at the bottom of their feet and toenails over the ends of the tops of their feet (San Diego Zoo Global Library). This enables them to grip loose, rocky landscapes like the Andes and minimizes damage to vegetation (Cheli et al. 2016, San Diego Zoo Global Library). The four subspecies of guanaco generally have the same coloration, but their coats contain tinges of yellow or red depending on where they are found (San Diego Zoo Global Library, Baldi et al. 2016). There is almost no variation in coloration and markings between individuals (Baldi et al. 2016). Guanacos have sharp front teeth which they use to "cut" plants for consumption, which they then swallow and regurgitate in a way that is similar to ruminants like cows and deer (San Diego Zoo Global Library). Although guanacos are generalists and can eat up to 100 different types of grasses, shrubs, berries, and leaves, the grasses, *Stipa* spp. and *Poa* spp., comprise about 40% of their diets (Baldi et al. 2001, Baldi et al. 2016).

Image 1. A herd of guanacos at site 4C.

Guanacos can run up to 60 kilometers per hour and are adept at jumping over 1-meter high livestock fences (San Diego Zoo Global Library, Baldi et al. 2001). They are diurnal animals, spending almost the entire day watching for predators and foraging (Baldi et al. 2016, Marino et al. 2008). Guanacos defecate in communal areas, which scientists and ranchers refer to as *bostaderos*, and return to these sites to ingest salts and other nutrients (Soca et al. 2016). Like many ungulate species, guanacos form herds to increase overall vigilance while maximizing individual time to forage (Marino et al. 2008, Marino et al. 2010). During the mating and calving season in the austral spring-summer (roughly September-January), guanacos follow a grouping pattern called resource defense polygyny where males defend smaller stretches of territory to attract females (Young et al. 2004). Strong male guanacos will defend a territory's boundaries throughout the mating and calving season regardless of their success in attracting females (Young et al. 2004). Females can move freely between these territories and will mate with the male defending the highest quality territory, giving birth to young in the late spring (Young et al. 2004, Marino et al. 2012). Groups at this time of year tend to be comprised of a single adult male guanaco, several female guanacos of varying age, yearling guanacos (> 1-2 years old) and calves (Young et al. 2004). Male guanacos let out a shrill sound, called a *relincho*, to alert others of the presence of danger or to threaten other males in territorial confrontations (* Victor Fratto). Male yearlings are expelled from their natal group when they reach sexual maturity at about 3 years of age and will often join "bachelor" groups comprised of young and old guanacos unable to defend their own territories during the mating and calving season (Young et al. 2004, Marino and Baldi 2014). During the austral fall and winter guanacos form larger non-territorial groups of both males and females of various ages (Marino et al. 2014, Young et al. 2004). Group size in all seasons is dependent on total resource availability and the risk of predation (Marino et al. 2014, Marino and Baldi 2014).

Image 2. A small group of guanacos at site 5A.

The guanaco's main predator is the puma (*Puma concolor*), but the Andean fox (*Lycalopex culpaeus*) has also been known to hunt young guanacos that are smaller in size (Novaro et al. 2009). The guanaco's main response to the sighting of a puma is flight, but they will kick, bite and chase foxes away from their young (Novaro et al. 2009). Guanacos can occupy ranges of only a few to hundreds of square kilometers (Baldi et al. 2016). In areas where snow will bury vegetation in the winter guanacos tend to migrate to lower elevations or to areas with more resources available (Baldi et al. 2016). In parts of the Andes, guanacos have been known to move through 900 km^2 areas, whereas, guanacos occupy territories of about 40 km^2 in Tierra del Fuego (Baldi et al. 2016, Flores et al. 2018). Guanacos are generally non-migratory in areas without snowy winters; and occupy minimal areas of 2-9 km^2 (Baldi et al. 2016, Marino et al. 2008). An individual guanaco's range is lowest during the mating season, when good grazing is not as difficult to find and males trade size for defendability when selecting a territory (Marino et al. 2012). Group and mating dynamics result in guanaco populations that are more spread out during the mating and calving season (Schroeder et al. 2014).

2. Guanacos, Livestock and People in Argentina

Historically, guanacos were an important food source for indigenous peoples throughout South America and the main source of protein and clothing for groups in the dry, resource-scarce mountains or Patagonian steppe (Moraga et al. 2014).

When Europeans first arrived in South America, it is estimated that guanacos numbered close to 50 million throughout the continent and about 7 million in Patagonia alone (Baldi et al. 2016, Baldi et al. 2001). European settlers introduced livestock to various parts of Argentina, and sheep farming in Patagonia sharply increased as European migrants settled in the area in the late 18th century (Baldi et al. 2016, Baldi et al. 2001). By the 1950s, Argentine Patagonia was home to about 22 million sheep (Baldi et al. 2001). Meanwhile guanaco populations were in steep decline throughout South America due to widespread hunting, competition with livestock, and exclusion from the most productive grazing lands (Baldi et al. 2016, Baldi et al. 2001, Moraga et al. 2014). In the 1970s, Argentina's guanaco population declined to an all-time low of about 600,000 individuals (Baldi et al. 2001).

Widespread hunting, chasing and exclusion through fencing together with competition for grazing and water from sheep and other livestock caused guanaco numbers to plummet to near extinction in most of Argentina – and to total extinction in much of South America. Today, guanaco numbers are estimated to be up to 97% lower than when Europeans first arrived (Baldi et al. 2016). In Argentina, guanacos only occupy 40% of their historic range and have been pushed into marginal or fringe habitats – such as forests instead of grasslands on Tierra del Fuego (Schroeder et al. 2014, Moraga et al. 2014). Still, guanaco numbers are slowly increasing since the 1970s: total numbers in South America range from 1.5-2 million and the IUCN currently classifies guanacos as species of Least Concern (Baldi et al. 2016). More than three quarters of these guanacos are in sparsely populated areas in Argentine Patagonia, about 14-18% are in Chile, and less than 1% are scattered in Peru, Bolivia, and Paraguay (Baldi et al. 2016).

The slow resurgence of guanacos in Argentina can be directly linked to a steady decline in "campo" or agricultural/animal-husbandry livelihoods (* Pablo Borboroglu). By 2001, the number of sheep in Patagonia dropped to 10 million (Baldi et al. 2001). As ranches are abandoned, livestock is removed and humans migrate to urban areas – freeing up large tracts of ranchland, resources and space for wildlife (Nabte et al. 2013, * Pablo Borboroglu). However, the legacy of conflict with humans is a highly fragmented metapopulation of guanacos, confined largely to areas with low human population density (Baldi et al. 2016). Patagonia is where guanaco populations are most continuous, but density is low (Baldi et al. 2016). This makes population groups vulnerable to stochastic events and lowers the overall genetic fitness of the species (Baldi et al. 2016, Flores et al. 2018).

Long-lasting impacts by livestock on the landscape also prevent guanacos from recolonizing certain areas. High numbers of livestock – especially sheep – have been allowed to overgraze much of the Patagonian steppe, reducing available forage overall and hampering the ability of many areas to “regrow” as paddocks confine animal movements (Baldi et al. 2001, Cheli et al. 2016). Overgrazing and the expulsion of guanacos – key seed dispersers - have led to a reduction in landscape heterogeneity and plant biodiversity at finer scales and enabled the expansion of less palatable species at the expense of others (Barri et al. 2016, Albert et al. 2015). This has led to a significant insect population and biodiversity losses – which in turn can further reduce biodiversity in plant communities (Cheli et al. 2016). In addition, livestock hooves cut into the ground in ways that the padded feet of guanacos did not – causing erosion (Cheli et al. 2016, Baldi et al. 2016). About 30% of land in Patagonia has been lost to desertification as a result of livestock-linked erosion (Baldi et al. 2001).

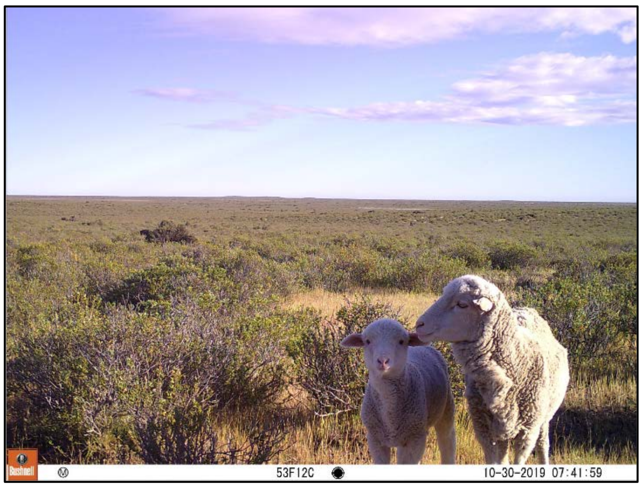


Image 3. Sheep at site 2C.

Guanacos are still widely considered “pests” by *gauchos,* or ranchers, throughout Argentina, and though indiscriminate hunting is no longer legal, there is little enforcement of hunting quotas (Conversations with Pablo Borboroglu and Victor Fratto). Guanacos are managed at the district level, and though baseline numbers are largely unknown, many district-level governments are quick to classify guanacos as a nuisance and attempt to outline mitigation strategies that usually consist of culling (Schroeder et al. 2014).

2. The Study Area

A. El Pedral

The study area is comprised of two properties: an eco-lodge that can house about 20 guests and a working sheep ranch, or *estancia*. Both are called El Pedral and were originally part of one large *estancia* founded in the early 20th century and split up in the 1990s (El Pedral). The *estancia* is still dedicated to sheep-rearing for wool production and (to a much smaller extent) meat production, particularly in the high tourist season from September to January (*Sebastian Stocker). The human settlement closest to the study area is the city of Puerto Madryn, nearly 70 km away. The total area of my study site is about 150 km^2, with the lodge de campo El Pedral comprising only 0.9 km^2 and the *estancia* El Pedral the rest (*Sebastian Stocker). The area receives about 200 mm of rain a year and contains arid plains, plateaus, and low hills (Matteucci 2012). It ranges in elevation from sea level to about 300m, and the average temperature is between 4°C to 21°C (U.S.G.S., Baldi et al. 2001). The coastline borders roughly half of the study area and is home to southern elephant seal and a growing Magallanic penguin colony part of the year and sea lions year-round. These stretches of coast are currently protected areas and will soon be declared part of another marine reserve (* Pablo Borboroglu). Protected status does not extend inland, and the nearest terrestrial protected area is the Peninsula Valdes, a UNESCO World Heritage Site, roughly 150 km away (* Victor Fratto, UNESCO).

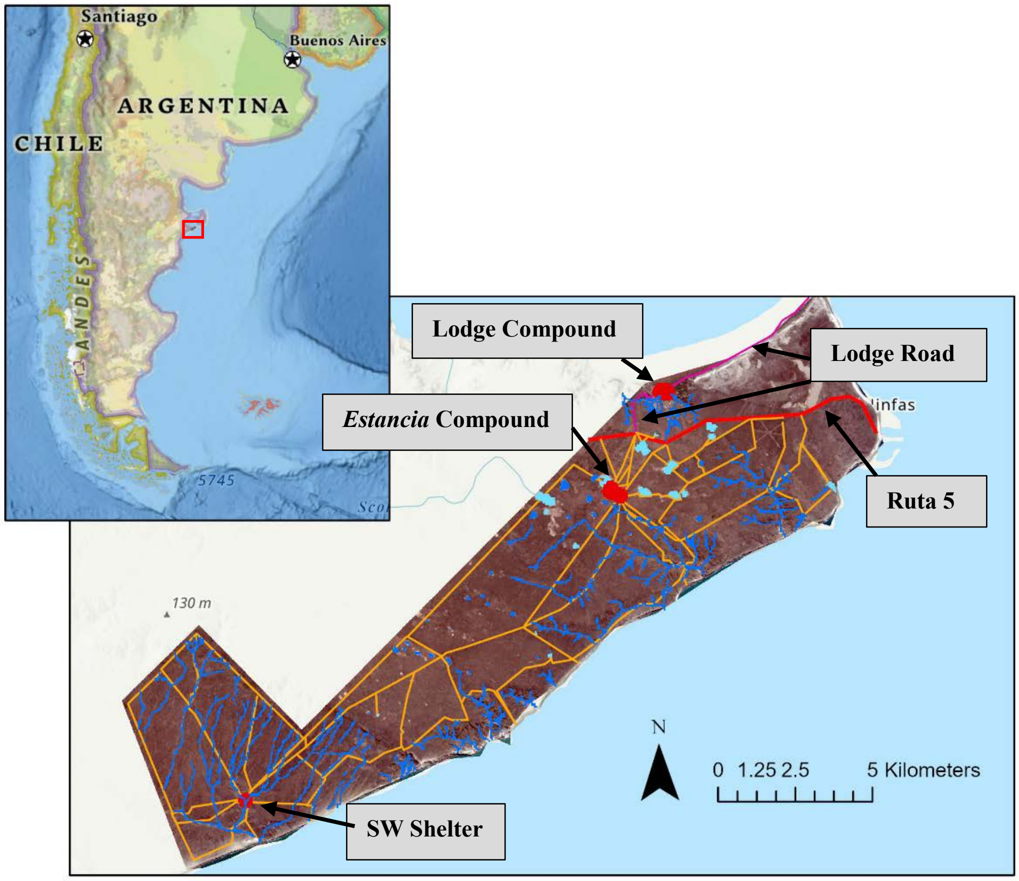


Figure 2. Map of study area. Sentinel 2 image is 10m resolution and clipped to El Pedral's borders. Orange roads are private, lodge road is in pink, and Ruta 5 is in red. The lodge, *estancia,*and SW shelter are also in red. Ephemeral water sources are in dark blue, and long-term water sources are light blue.

The *estancia* contained 4,230 sheep at the time of study (*Miguel). The lodge also purchases sheep from the *estancia* and keeps roughly 10-40 on the property from August to April to butcher and serve to tourists, and sheep from the *estancia* regularly graze on lodge property. The average sheep population density is 28.4 sheep per km^2 throughout the entire study area. However, the *estancia* is divided into 10 paddocks of varying sizes each containing 10-800 sheep, so the density varies in each paddock (*Miguel). The *estancia* manager did not know the area of each paddock, but most paddocks in this part of Patagonia are over 25 km^2 in area (Baldi et al. 2001). I was unable to record the GPS locations of the perimeters or to measure the areas of each paddock.

The study area is sparsely populated most of the year, but it will see higher numbers of people concentrated in the lodge area in the north during the tourist season. Interactions with humans are least likely from April to September while the lodge is closed, and fewer people come out to Punta Ninfas to fish. September to February/March is roughly when the area's elephant seal and penguin colonies are inhabited, and southern right whales can be seen from shore in the nearby gulf, and the lodge is at its busiest from October to January when tourists come to see all three. The lodge can house up to 40 people (staff and guests), with up to 150-day visitors who only see the lodge compound, the lookout to the elephant seal colony, and the penguin colony for a few hours. These are maximum estimates, but usually the number of people present at the lodge is much lower. One unpaved public road cuts through the northern part of the property and is used by tourists and people from neighboring cities to access Punta Ninfas. In the warmer months (October to March) the road will see a few cars a day, primarily residents of Puerto Madryn, Trelew or another *estancia* going to fish.

The *estancia* has two full-time residents, the caretaker and his wife, and one part-time resident *gaucho* (i.e., ranch hand) who works on the *estancia*. Four to five times a year, the *estancia* hosts groups of roughly 20 people who come to help with the bi-annual sheep shearing and quarterly sheep marking and breeding (* Miguel). Almost all work is performed in the *estancia's* compound in the northwestern part of the property, although occasionally groups of about 10 people will go to the southwestern area to a small shelter where they mark and separate the sheep that range in more distant paddocks (* Miguel). More commonly, sheep are driven to the northwestern compound by a few *gauchos* on horseback. While the shelter in the southwestern part of the *estancia* occasionally hosts the caretaker or a *gaucho* overnight, most human activity is concentrated around the northwestern compound. The caretaker and *gaucho* make daily rounds to visit various parts of the property by car or on horseback to check on the condition of wells, fences, and sheep. Aside from these visits however, human activity is concentrated in a few spots in the northern part of the property. Most of the study area only sees a couple of people three or less times a week.

About 140 kilometers of road run through the study area, and none are paved. Roughly a 10.5 km stretch of that is the public road (Ruta 5), about 9-10km lead down to the lodge and penguin colony and 3.5 km lead from Ruta 5 to the *estancia* compound. These are the most trafficked stretches of road, while the remaining roughly 120 km of roads are private, and used only by a few people (Google Earth).

Image 3. A road in the southwestern part of the *estancia.* All roads are unpaved in the study area.

B. Guanacos at El Pedral

Average guanaco densities in Argentina are between 1-7.5 per km^2, but in many parts of Chubut province this number can drop to 0.46 per km^2 on some ranches (Baldi et al. 2016, Marino et al. 2008, Burgi et al. 2012). On the Peninsula Valdes (where there is no hunting permitted), average density is 5 guanacos per km^2 (Marino et al. 2008). There are no population density estimates for guanacos at El Pedral, but density is likely on the lower end of this estimate given its distance from protected areas. Occasional hunting of guanacos by *gauchos* is known to occur at El Pedral. Guanacos are hunted for their meat throughout nearby *estancias*, and the practice is justified due to perceived high levels of competition with sheep (*Victor Fratto).

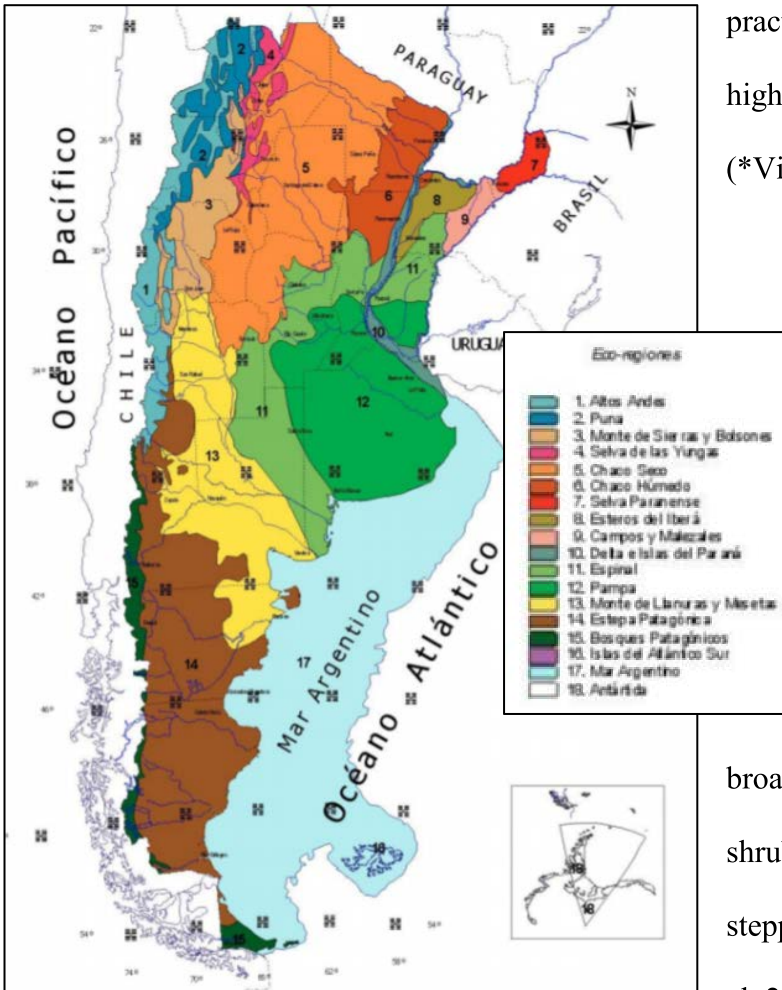


Figure 3. Eco-zones of Argentina (Quintana, R.D. 2008).

Because of its arid climate and hardy vegetation, the area is considered part of the plains and plateaus of the monte eco-region (Matteucci 2012, Figure 3). The vegetation patches that characterize this region can be broadly grouped into 4 communities: shrub-steppe, grass-steppe, shrub-grass steppe and dwarf-shrub steppe (Burgi et al. 2012). Scientists have observed that guanacos prefer grass-steppe and dwarf-shrub steppe on the Peninsula Valdes (Burgi et al. 2012, Fig. 4). There is no information on the vegetation composition of El Pedral's landscape, but having walked through much of the property, I saw key species from each of these four community types. The most common species I encountered were from the shrub-grass steppe and shrub-steppe groupings: *Chuquiraga avellanedae* and *Schinus johnstonii* (Burgi et al. 2012, Fig. 4).

Figure 4. Vegetation communities in Peninsula Valdes and nearby areas (Burgi et al. 2012).

Shrub steppe	Grass steppe	Shrub-grass steppe	Dwarf-shrub steppe
Plant: *Schinus johnstonii* **Avg. height**: 40-120 cm **Plant**: *Lycium chilense* **Avg. height**: 50-100 cm	**Plant**: *Nassella tenuis* **Avg. height**: 20 cm	**Plant**: *N. tenuis* (grass) **Avg. height**: 10 cm **Plant**: *Chuquiraga avellanedae* (shrub) **Avg. height**: 50-60 cm	**Plant**: *Hyalis argentea* **Avg. height**: 50 cm
 *Schinus johnstonii*  *Lycium chilense*	 *N. tenuis*	 *Chuquiraga avellanedae*	 *H. argentea*

Because El Pedral does not get snow, guanacos likely do not migrate seasonally in search of food (Baldi et al. 2016, Marino et al. 2008). A few natural and manmade lagoons (*tajamares*) contain water most if not all year, swelling to their largest size in the fall and winter months and shrinking to a fraction of their capacity in the summer months (* Miguel and Victor Fratto). All but five of these long-term water sources are concentrated in the northwest part of the property, most within 5 km of either the lodge or *estancia* compound. Many depressions in the landscape and beds in canyons become ephemeral water sources during rainfall events, but by December most of these are completely dried out (* Miguel and Victor Fratto, Baldi et al. 2001). These ephemeral water sources are scattered throughout the property (Fig. 5).

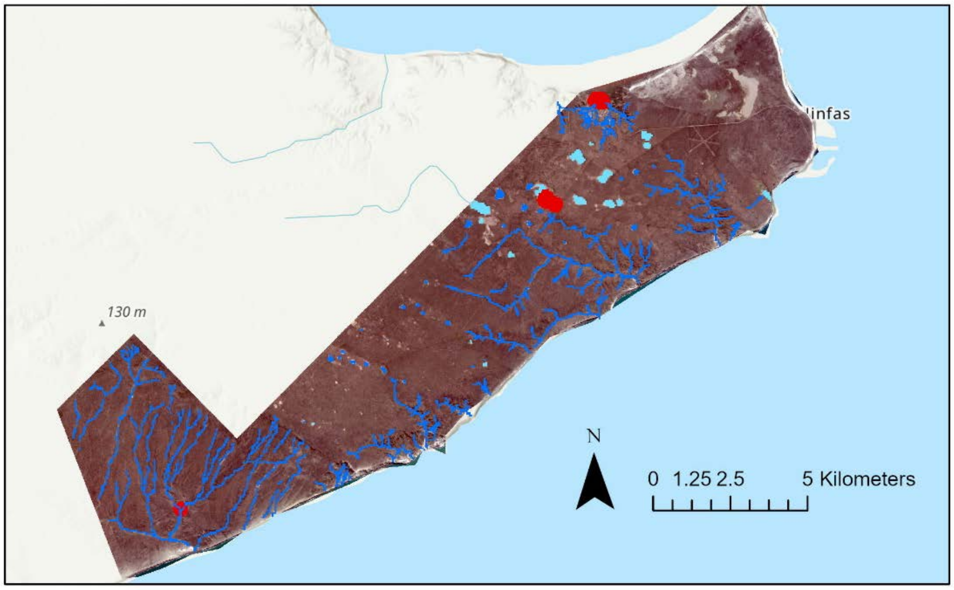


Figure 5. Map of El Pedral showing ephemeral water sources (in dark blue) and long-term water sources (in light blue). The lodge and *estancia* compounds and SW shelter are visible in red.

METHODS

I compared the results from 30 camera traps that were deployed throughout the property to the results of hypothetical models using least cost pathways (LCP) and site ratings using Zonal Statistics (ESRI). Then I looked at whether guanacos altered their spatial distribution at El Pedral based on human presence using distance analysis (ESRI). The results of my fieldwork represent observed guanaco distribution while the results of my hypothetical – or null – models represent predicted guanaco distributions. Expert and local knowledge, as well as scientific literature, informed the parameters of the null models. Presence/absence was counted to assess the frequency of guanaco encounters for all results (photos, in-person sightings and null models) and statistical analysis was used to compare guanaco encounter predictions by the null models to observed guanaco encounters.

1. Assessing the Observed Scenario

A. Fieldwork in Argentina

Guanacos are most often studied in person by walking or driving along transect lines and recording encounters. By using these methods however, scientists can bias results in species that avoid humans (Balsi et al. 2016, Iranzo et al. 2013). I specifically wanted to look at the possible effect human presence might have on guanaco distribution at El Pedral, so I chose to use camera traps for the fieldwork portion of my study instead of doing a transect study. Camera traps are a popular tool for looking at animal distribution because they can capture the reality of a habitat without factoring in the skewing effect human presence can have on animal behavior (Jimenez et al. 2010).

I conducted fieldwork at El Pedral from October to December of 2019. I used Bushnell Trophy Cameras that capture images within a 35 degree-wide arc. When cameras were set in sunny locations the motion sensor was easily triggered by shadows and vegetation movement, exhausting camera's batteries and filling the memory card. My study area was devoid of trees and shade and was constantly windy, so I opted to use Field Scan mode to avoid this potential problem. When set to Field Scan, the camera is programmed to take a single picture at designated time intervals for certain amounts of time and can capture animals that are between 49-137 meters away (Bushnell). I am 1.75 m tall – only a little shorter than an adult guanaco – and when I tested the cameras, they captured me reliably when I stood 75 to 100 meters away. To reduce the likelihood of missed encounters, I programmed my cameras to capture 1 picture per minute, 24 hours a day and I switched the motion sensor to Auto.

I used a random allocation process to select my camera sites to avoid placement bias and to cover sites at various distances from areas frequented by humans. I used QGIS to randomly assign 40 points throughout the property, and then I selected 30 accessible points. Most sites were less than one guanaco home-range (so less than 4-5 km per minimal range) away from the next nearest site, which is considered acceptable for large, easy-to-see species if the study does not intend to measure population density (Marino et al. 2012, Radovani et al. 2014).

Camera locations may not be random with respect to guanaco density, but I do not believe this constitutes bias given that I had no prior knowledge of guanaco distribution at El Pedral when assigning sites and the premise of the study was to look at these encounters spatially (Gray et al. 2018, Howe et al. 2017). I only had 5 cameras (and one backup), so I rotated them weekly to cover as much of the property as possible in 6 weeks. For the size of my study area, 30 sites provide a good sample of area (Chauvenet et al. 2017, Jimenez et al. 2010, Radovani et al.

2014). While the short deployment times at each site could bias results for harder to find species, like pumas, guanacos are not elusive by nature, relying instead on herd vigilance to guard from predators (Marino et al. 2010). Guanacos are also taller than the vegetation present in my study area, so they are more likely to be spotted by my cameras if they are present at a site (Burgi et al. 2012).

I used the Gaia GPS app to locate the pre-determined site locations as I walked, and then placed the camera within 100 meters of the pre-determined site. I then searched for areas that might be used by guanacos by looking for animal trails, scat, prints, shelter and/or grasses to determine the final placement of my cameras. Four sites are more than 100 meters away from their GIS-selected locations due to complications in the field: 5A, 5B and 5C were still deployed according to schedule but in different locations, but I replaced site 4E (camera malfunctioned and did not take any pictures) with an additional site which I deployed two weeks later. I recorded data on landscape features at each camera site, and signs of animals or animal and vehicle encounters on each visit (See Appendix).

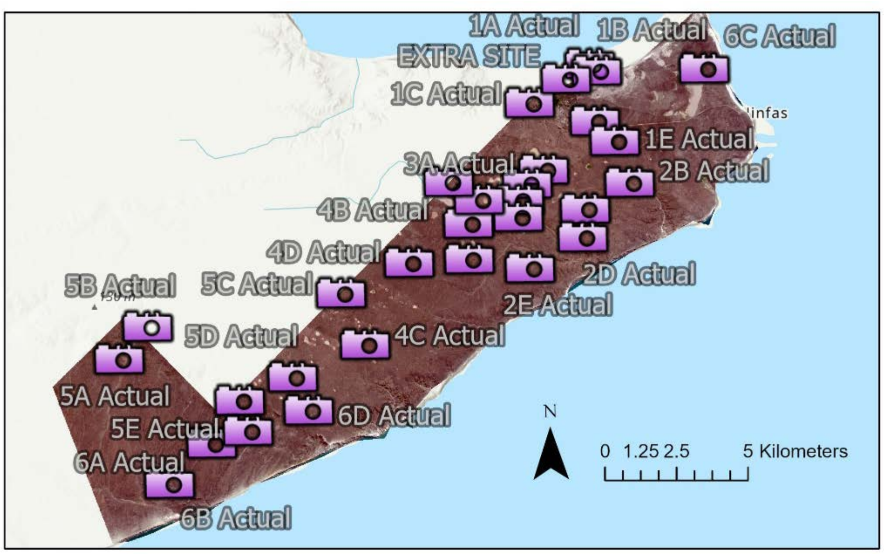


Figure 6. Camera site locations.

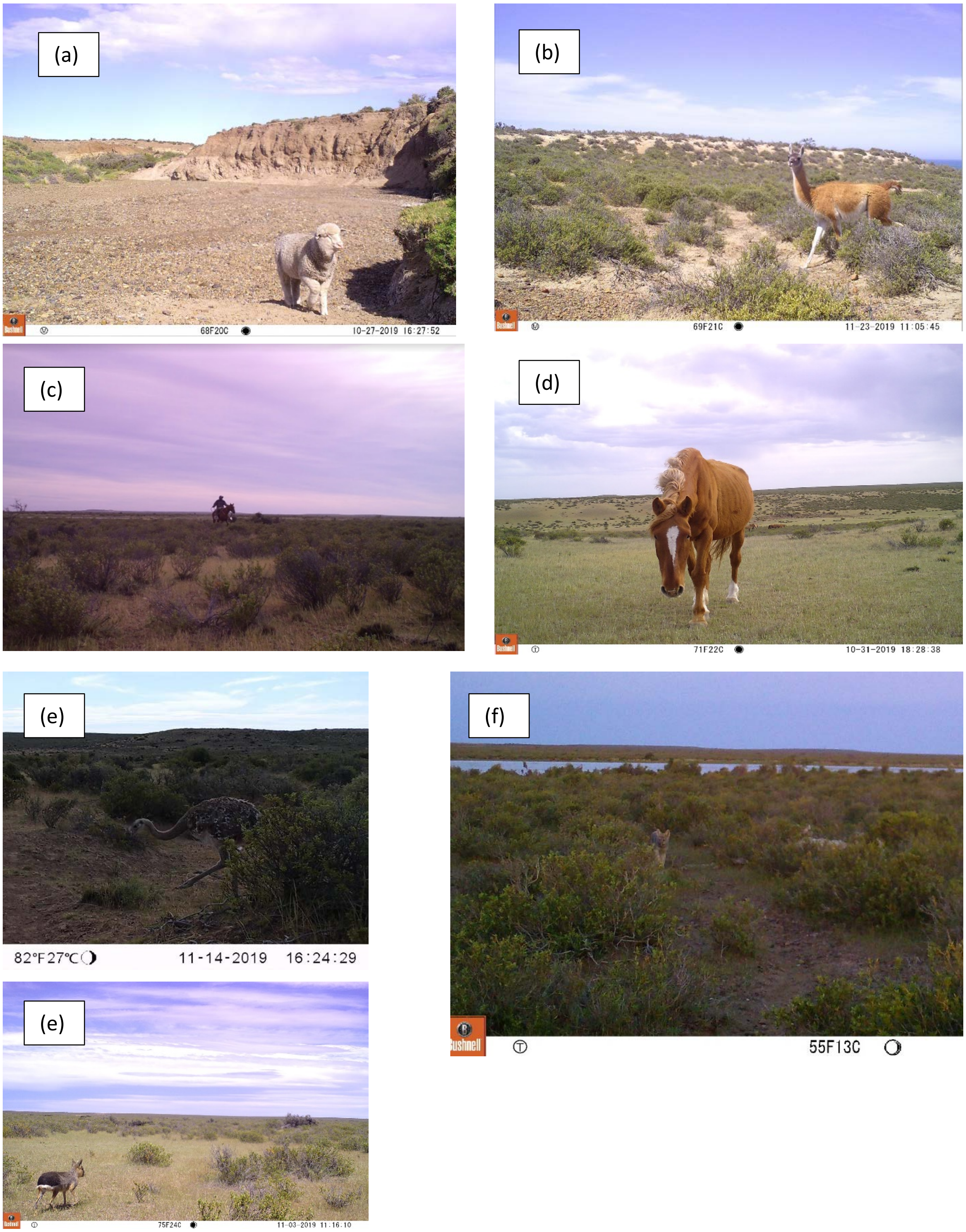
B. Photo Classification

My camera traps took a total of 304,117 photos. Because this study only looks at presence/absence, photo classification focused on counting the number of guanaco encounters (i.e. the total number of photos in which guanacos could be clearly identified) at each site. Animals were only recorded if they were clearly identifiable to ensure I was analyzing reliable data for spatial patterns.

Figure 7. Table describes the categories used to count presence/absence of various species in the photo results.

Category	Data Recorded
(a) Sheep	# of individuals, Name of file, Date and time of picture
(b) Guanacos	# of individuals, Name of file, Date and time of picture
(c) Humans	Classified them if they were on foot, in a vehicle or on horseback. Horses or dogs around human equipment and/or humans were also classified as Human. # of individuals (humans and animal if present with them), Name of file, Date and time of picture
(d) Horses	Classified if they weren't around human equipment and/or humans: # of individuals, Name of file, Date and time of picture
(e) Other (Choique, Mara, European Hare, Peludo)	Name of file
(f) Predators (Pumas, Zorro Colorado, Zorro Gris, Gato Montes, Gato Peajonal)	Name of file

Image 5. Photos of certain species were counted for presence/absence. See Fig. 6 for classification categories.



C. Distance Analysis

To spatially analyze how observed guanaco encounters related to human presence, I created buffers around the two human residence areas (the lodge compound and the *estancia* compound) of various distances in ArcGIS. I did not include the SW shelter in this assessment because it rarely has humans, unlike the lodge and *estancia* compound. The 4 distance categories I used were: 0-2 km away from a human residence, 2-5 km away, 5-10 km away and 10-17 km away.

I then created one shapefile that showed all in-person encounters and another shapefile showing all camera sites. I was able to count the number of in-person encounters that occurred in each distance category by placing these shapefiles atop the distance buffers. After classifying all camera trap photos and counting total photographed encounters at each camera site I did the same to then calculate the number of photographed encounters in each distance category. The same calculations were performed on photo encounters with sheep to compare to observed results for guanacos (See Appendix).

Finally, I reclassified the distance buffers according to the total number of observed guanaco encounters that occurred within each distance range.

2. Null Models: Assessing the Hypothetical Scenario

I produced two models: one that would rate sites according to their average value to guanacos and one that predicted guanaco paths. Both models were assessed at or around the camera sites to compare to observed results. I created both models in ArcGIS Pro 2.5. I used a Sentinel 2 image with a 10-meter resolution taken on October 4, 2019 to perform the image classification, and my own GPS data to build shapefiles for important features. I used shapefiles showing all camera locations and in-person guanaco sightings to perform several of the counts detailed below. Fencing was not dealt with in this study because I was unable to map and measure all fences on the property, and because fencing does not appear to inhibit the movement of adult guanacos (Baldi et al. 2001, Burgi et al. 2012). Some camera trap studies have ignored fencing when the animals can jump over or under them (Chauvenet et al. 2017).

A. Site Ratings

To rank different areas of El Pedral, I assigned all landscape features a value to guanacos (Meek et al. 2014, Shah and McRae 2008). I performed a supervised, object-based classification in Arc on the Sentinel 2 image. Even at a 10-meter resolution, the classifier could not distinguish between human buildings (which are few, small and low), bare ground, and water bodies (which are brown due to high sediment content, so I classified the landscape into only three categories: Less Vegetation Cover/Bare Ground, Sand Dunes, and Vegetation. I manually created rasters for all roads, human buildings, long-term water sources, ephemeral water sources, and canyons. I added buffers on all sides of the roads and human compounds to account for guanaco avoidance of these structures (DeMars et al. 2020, Mulero et al. 2016, Leblond et al. 2013, St-Louise et al. 2014). In D'amico et al, ungulates were not observed closer than 200 meters away from less-trafficked, unpaved roads in a protected area in Spain (D'amico et al. 2016). The busiest road in my study area – Ruta 5 – matched the description of the roads used in the study, so a 200-meter buffer was appropriate for my models. I could not find a specific distance buffer for human houses or small compounds, so I also added 200-meter buffers to the lodge and *estancia* compounds and the SW shelter. I assigned each feature a value based on scientific literature, local and expert knowledge, and my own observations on-the-ground and joined all features into a single, weighted raster (Human Weighted Layer, or HWL) (Fig. 7). I did this a second time to create a weighted raster without human features (No Human Weighted Layer, or NHWL).

Figure 8. Values assigned to landscape features used in creating both weighted layers.

Feature	Assigned Value	Justification
Human Compounds	0	Guanacos known to avoid human structures (Leblond, Iranzo)
Roads	2	Guanacos are known to avoid roads (Malo, Donadio, D'amico)
Sand Dune	3	Sand dunes do not contain vegetation and expose guanacos to predation, so are of lower value (Marino and Baldi)
Bare Ground/Less Veg Cover	5	Often degraded land so not of high value (Baldi 2001, Nabte)
Ephemeral Water Sources	8	Water is scarce in this area so this of high value. However these dry up, some only lasting for a few days after a rain event (*Miguel, *Victor)
Canyons	9	Provide shelter from predators, so of high value (*Victor)
Veg Cover	9	Provides grazing to guanacos so of higher value (Baldi 2001)
Long-Term Water Sources	10	Water is scarce in this area so this of high value. (*Miguel, *Victor)

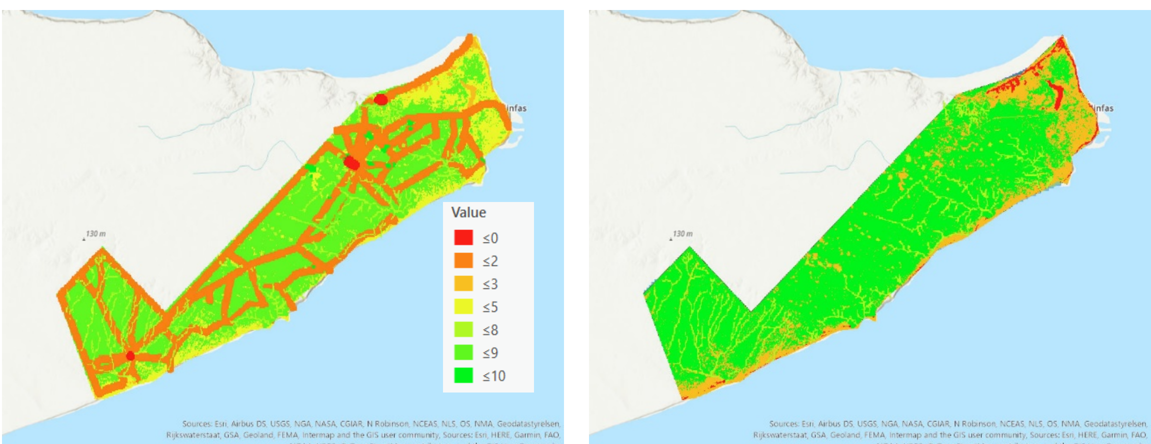


Image 6. Final HWL (left) and NHWL (right).

Typically, the average herd size is lowest and individual guanacos are spread out during the spring and summer mating season, with the fall and winter reversing these trends (Schroeder et al. 2014). The minimal range for non-migratory guanacos is 2-9 km^2, and in Chubut, male guanacos have been recorded defending territories of about 4-6 km^2 during mating season (Baldi et al. 2016, Marino et al. 2008). Because this study took place during mating and calving season and it is unlikely that guanacos at El Pedral migrate, I used the average of the minimal range of non-migratory guanacos to determine the size of territories around each camera site, 5.5 km^2.

Once the weighted layers were complete, I used the Zonal Statistics tool to assess the average value of the areas around each camera site for both the HWL and the NHWL. Zonal Statistics calculates the mean of all pixels of a weighted raster in a specified area, giving the average value of an area based on the landscape features it encompasses (ESRI) Each 5.5 km^2 camera area received one result for the assessment using the HWL values and another result for the assessment using the NHWL values. The resulting range of averages were then divided into five smaller ranges and assigned a rating of 1-5 (lowest to highest value to guanacos). Camera areas were then rated accordingly. These results constituted the expected values I used for statistical analysis.

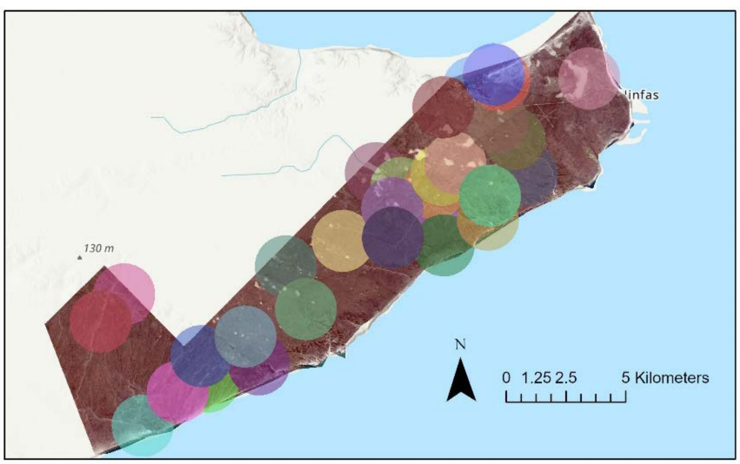


Figure 9. All 5.5 km^2 areas around camera sites used to calculate site ratings.

To create site ratings for observed results, I first counted the total number of photo encounters at each camera site as well as the total number of in-person sightings within the corresponding 5.5km^2 area (Fig. 8). The percentage of total encounters at each site area was calculated in excel and their ranges divided into 5 categories to rate each area from 1-5, as I did with the null model rankings.

How Ranking Ranges were Determined:		
Observed	Percentage of Encounters	Rating
	0	1
	0.01-1.0	2
	1.01-5	3
	5.01-10	4
	10.01-36	5
HWL	Mean Weighted Value	Rating
	0-4.63	1
	4.631-5.68	2
	5.681-6.67	3
	6.671-7.55	4
	7.551-8.89	5
NHWL	Mean Weighted Value	Rating
	0-7.22	1
	7.221-8.15	2
	8.151-8.53	3
	8.531-8.699	4
	8.700-8.90	5

Figure 10. Ratings values based on Observed Encounter Percentages, the HWL, and NHWL.

Each camera site area received a rating of 1-5 for three scenarios: the average value of the weighted layer containing human features, the average value of the weighted layer containing human features, and the reality as determined by camera and in-person encounters.

B. Creating Least-Cost Pathways

I calculated the LCPs for guanacos across three different area scenarios: the whole property (150 km^2), within 40 km^2 territories, and within 5.5 km^2 non-migratory territories. These areas are based on the territory size habits of guanacos in different parts of Argentina because I could not be sure whether guanacos at El Pedral were migratory or non-migratory.

To calculate LCPs in each scenario, I created a gridded feature layer for each individual territory under each scenario: 1 border for the whole property, 3 borders for the 40 km^2 territories, and 19 borders for the 5.5 km^2 territories that contained camera sites. I then made a second version of the HWL which reversed the values assigned to each landscape feature to indicate how difficult or easy it is for guanacos to pass through them (1 is easiest, 10 is most difficult). All landscape features that had been of low value to guanacos in the first weighted layer were re-classified with high values and vice versa. LCPs were created using the Cost Connectivity Tool, and I used in-person sightings and long-term water features (of high value to guanacos) as "source" locations (i.e. start/end points to connect). I then created 100-meter buffers around camera sites because the cameras can see up to 100 meters away (Bushnell).

I recorded the number of times an LCP crossed within 100m of a camera site in all three area scenarios; an intersect meant that guanacos would be encountered within 100 meters of that camera site. LCP encounters were recorded using 0 to indicate no encounter and 1 to indicate one or more encounters had occurred within 100m of a site. These results constituted the expected values I used for statistical analysis.

To prepare photo and in-person encounter results for comparison, I counted all the sites that had yielded photo encounters and whether any in-person encounters had occurred within 100 meters of a site on Arc. The number or type of encounter was not recorded for this comparison, just whether an observed encounter had occurred at a site. Observed encounter information was also recorded using 0 and 1.

C. Observed vs. Predicted Guanaco Distributions

Site Ratings: Using a two-tailed equal variance t-test, I examined whether there were differences between the predicted guanacos' distribution with human features (null HWL) and observed guanacos' distribution ratings. I also conducted a two tailed non-equal variance t-test to examine whether there were differences between the predicted guanacos' distribution without humans (null NHWL) and observed guanacos' distribution ratings. Both tests used a *P* value cutoff of 0.01.

Figure 11. T-test set-up for Site Ratings Results.

Does Ranking change for camera 5.5km2 sites between (1. reality and Human weighted averages) and (2. Reality and No Human Weighted Averages)?	H0 is NO change across sites	H1 there is a change across camera sites	Alpha =0.1

<u>*LCPS*</u>*:* I used chi-square tests to look at whether there were differences between predicted encounters using LCPs and observed guanaco encounters. To calculate the expected values, I calculated the sum of all sites that had encountered an LCP within 100 meters and the sum of all sites that did not for each territory under each territory size scenario. Observed values were also calculated for each territory size scenario.

I could perform chi-square tests for the 150 km^2 scenario and for each of territory in the 40 km^2 scenario because these scenarios contained enough data for comparison (more than five cameras were encompassed by each territory). I used a *P* value cutoff 0.05 for ch-square tests for all territories under all scenarios.

Does encounter status change between LCPs NonM and Reality?	H0 is NO change across camera sites	H1 there is a change across camera sites	Alpha = 0.05

Figure 12. Chi-square test set-up for LCPs Results.

However, I did not perform a chi-square test for the results from the 5.5 km^2 scenario because most territories in the 5.5 km^2 scenario did not contain more than 1-2 cameras, which is too little data for statistical comparison. I recorded these results in a table and counted the number of times a predicted status matched the observed status.

RESULTS

The cameras took a total of 304, 117 photos at all sites, of which 14,443 were classified. Total classification by species is in Fig. 13.

Percentage of Animal Sightings at Study Sites	
Animal	**Percentage**
Guanacos	12.33%
Sheep	74.86%
Humans	0.24%
Horses	9.06%
Dogs	0.03%
Other Wildlife	3.47%
Predators	0.01%

Figure 13. Total classification results by encounter %.

1. Distance Analysis

I calculated the total encounters of guanacos both in-person and photo and aggregated these by distance away from the nearest human residence. I performed the same calculation for photo encounters with sheep to compare sheep distribution to guanaco distribution.

Figure 14. Guanaco encounters by Distance.

Summary of Total Guanaco Encounters					
	Distance Away				Total
	0-2 km	2-5 km	5-10 km	10-16 km	
Camera Encounters	0	82	39	1661	1782
Percentage of Camera Encounters	0.00%	4.60%	2.19%	93.21%	
In-Person Encounters	3	7	12	14	36
Percentage of In-Person Encounters	8.33%	19.44%	33.33%	38.89%	
Total of All Encounters	3	89	51	1675	1818
Percentage of All Encounters	0.17%	4.90%	2.81%	92.13%	

Figure 15. Sheep photo encounters by distance.

Summary of Total Sheep Camera Sightings					
	Distance Away				Total
	0-2 km	2-5 km	5-10 km	10-16 km	
Camera Sightings	1921	4785	732	3536	10974
Percentage of Camera Sightings	17.51%	43.60%	6.67%	32.22%	

Calculating the percent of frequencies within each distance category shows that almost all guanaco encounters occur in the area farthest away from a human residence – and that the total number of encounters in these sites is nearly 20 times greater than the next highest frequency.

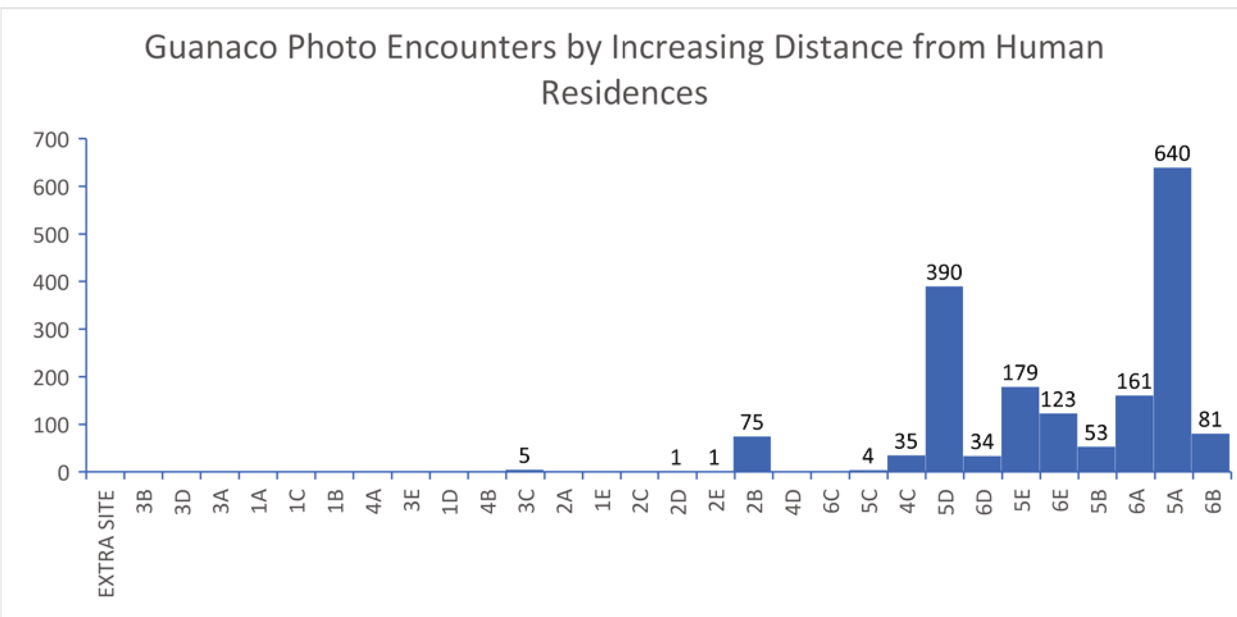


Figure 16. Guanaco photo encounters by distance.

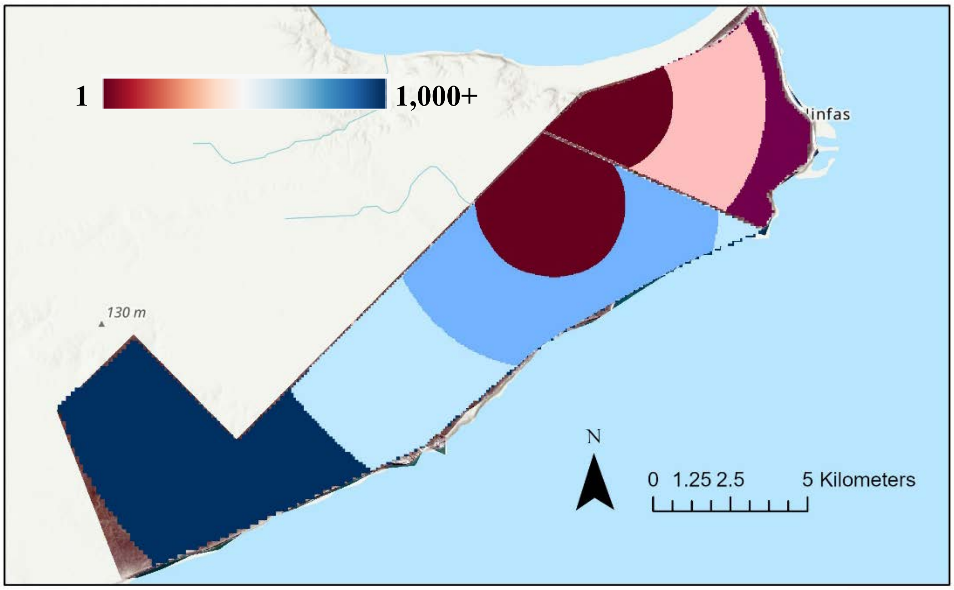
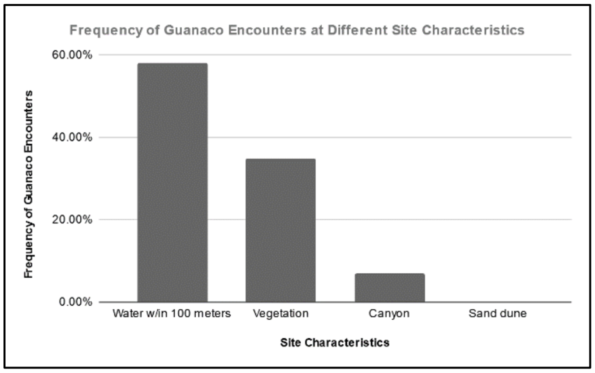


Figure 17. Guanaco encounter frequency by distance map.

I also calculated guanaco photo encounter frequency at different types of sites and then aggregated these by distance categories to look at how landscape features might affect distribution more than human presence. Guanaco encounter rates increased regardless of the main landscape feature at the site as distance from human residences increased (Fig. 18).

Figure 18. Guanaco photo encounters by site characteristics in order of increasing distance away from human residences.



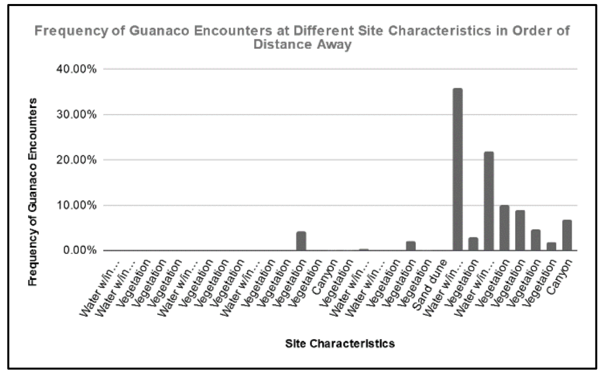


Table of the Frequency of Water within 100 m by Distance

Distance Away	Site	% of Photo Encounters
0-2 km away	EXTRA	0.00%
	3B	0.00%
	3A	0.00%
2-5 km away	1D	0.00%
	3C	0.28%
	4B	0.00%
10-16 km away	5A	35.91%
	5D	21.89%

Table of the Frequency of Unpaved Roads by Distance

Distance Away	Site	% of Photo Encounters
0-2 km away	EXTRA	0.00%
	3B	0.00%
	1C	0.00%
	3A	0.00%
2-5 km away	1D	0.00%
	1E	0.00%
	2A	0.00%
	2C	0.00%
	2D	0.06%
	4B	0.00%
10-16 km away	5A	35.91%
	5B	2.97%
	5D	21.89%
	6D	1.91%

2. Site Ratings: Observed vs. Predicted Guanaco Distributions

	at Alpha=0.1	< or > 0.1	
Observed-HWL	0.2399292	>	Don't reject
Observed-NHWL	0.06584355	<	Reject Null

Figure 19. T-test comparison results.

The predicted guanaco distributions with humans (based on the null HWL ratings) was not significantly different than the observed guanaco distribution ratings (*P*=0.240). The predicted guanaco distribution without humans (based on the null NHWL ratings) was significantly different from the observed guanaco distribution ratings (*P=0.065*).

The t-test results show that the NHWL ratings are bad predictors for the value of an area to a guanaco. The HWL ratings can predict an area's value with some amount of accuracy, but the low *P*=0.240 value indicates low correlation and that it is still not reliable in predicting guanaco encounters.

3. Least-Cost Pathways

	40 km2 Territory 1	40 km2 Territory 2	40 km2 Territory 3	40 km2 TOTAL all 3
P value result	0.035938931	0.540291375	0.00026073	0.000553718
P value < or > alpha = 0.05	<	>	<	<
Reject or Accept H0?	Reject	Accept	Reject	Reject
	150 km2			
P value result	0.0168			
P value < or > alpha = 0.10	<			
Reject or Accept H0?	Reject			

Figure 20. Chi- square test comparison results.

The chi-square test comparing the total encounter at LCPs across 150 km scenario to the observed encounters at all cameras resulted in *P=0.0168*, below the cutoff of 0.05. The LCPs based on the HWL across the property were not good predictors of guanaco encounters that had occurred within 100m of a camera site.

Under the 40 km^2 scenario, chi-square tests also resulted in *P* values below 0.05 for territory 1 (*P*=0.0359) and territory 3 (*P*=0.0003). The LCPs based on HWL across territories 1 and 3 were also not good predictors for guanaco encounters within 100m of a camera site. The chi-square test performed on data from territory 2 resulted in a *P* value higher than the cutoff of 0.05 (*P*=0.5403), so the LCPs predicted guanaco encounters within 100m of a camera site well in territory 2. However, when the total number of predicted encounter at LCPs for all cameras in this scenario (regardless of the territory they were in) was compared to total observed encounters, the chi-square test resulted in *P*=0.0006, which is significantly less than the cutoff of 0.05. This indicates that taken even when split into territories of 40 km^2, the LCPs based on the HWL are not still not good predictors of guanaco encounters across the whole property.

Site	5.5km2 areas - LCPs intersect w/in 100m of cameras	Encounters (camera and sightings) w/in 100m	Match?
2B	0	1	0
2D	0	1	0
2E	0	1	0
3C	1	1	1
4C	1	1	1
5A	1	1	1
5B	0	1	0
5C	0	1	0
5D	1	1	1
5E	1	1	1
6A	0	1	0
6B	1	1	1
6D	0	1	0
6E	0	1	0
EXTRA	0	1	0
Total Observed Encounters		15	
Total Matches			6

Figure 21. LCP results for 5.5 km^2 scenario.

There was not enough data per 5.5 km^2 territory to run chi-square tests for this scenario. However, I did count the number of cameras at which the LCPs predictions for guanaco encounters within 100m matched or did not match the observed results. Guanacos were encountered within 100m at 15 sites by cameras and/or in-person sightings. The LCPs based on the HWL within 5.5 km^2 territories predicted guanaco encounters within 100m at 6 of these sites, but failed to predict for encounters at the remaining 9 sites. The LCPs under this scenario yielded a match rate of just 40%. This means that this model at 5.5 km^2 is also not a good predictor of guanaco encounters.

ANALYSIS

The null models are generally not good predictors for guanaco distribution at El Pedral.

Comparisons between ratings at each 5.5 km^2 site based on the HWL and the NHWL, and observed encounters showed that the NHWL ratings were much less accurate than the HWL at predicting the observed guanaco encounters. This confirms that humans do affect guanaco distribution at El Pedral, as the addition of human features to the landscape greatly increased the accuracy of the model.

However, although the t-test result comparing observed encounters-based ratings to the HWL ratings were not significantly different, this only indicates a statistically similar spread of data and does not account for the differences between ratings on a site-to-site basis. A visual comparison of the HWL ratings and the frequency of guanaco encounters by distance shows that most of the sites on which the model placed the highest and lowest value do not follow the trend laid out by the observed encounter frequency data (Fig. 16).

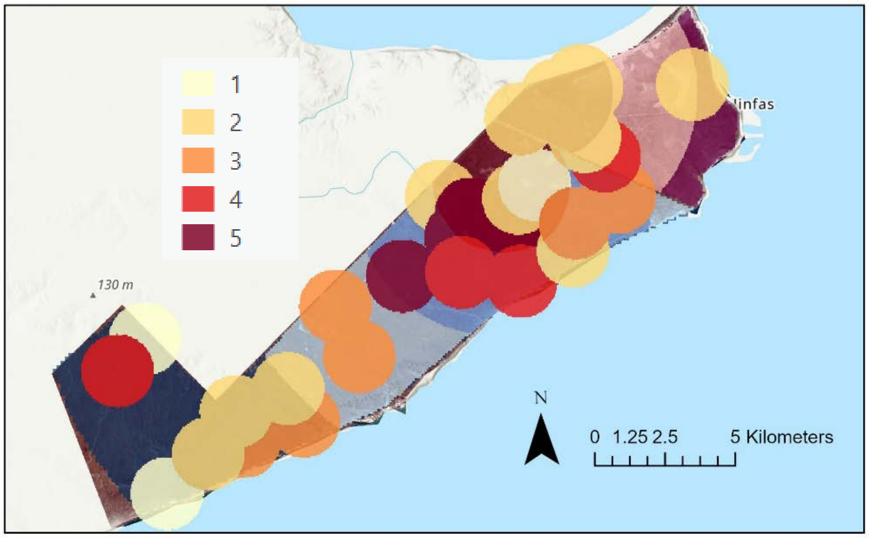


Figure 22. HWL ratings results and Observed guanaco encounter frequencies by distance.

The HWL model rates many areas that are less than 5 km away from a human residence highly (4, 5) while giving lower ratings (1, 2) to all but two of the sites that are 10-16 km away from a human residence. The sites with ratings of 1-3 in the 10-16 km range account for more than half of all guanaco encounters, while the remaining sites account for just 8% of all guanaco encounters.

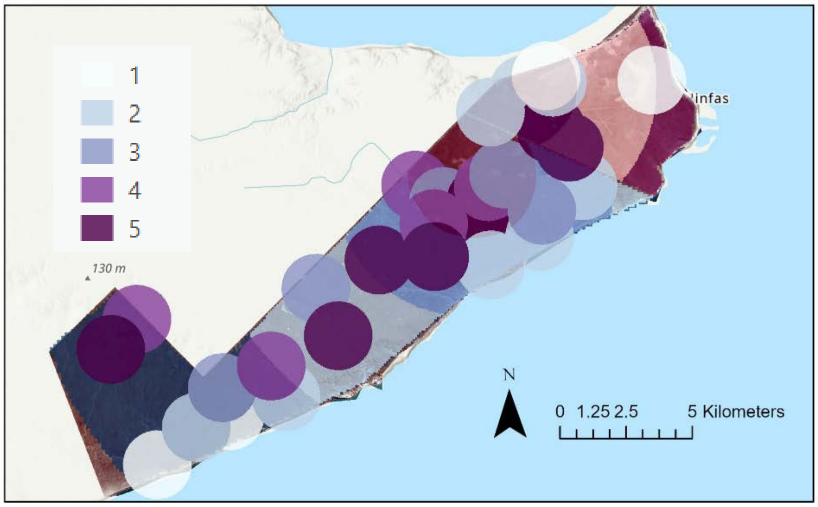
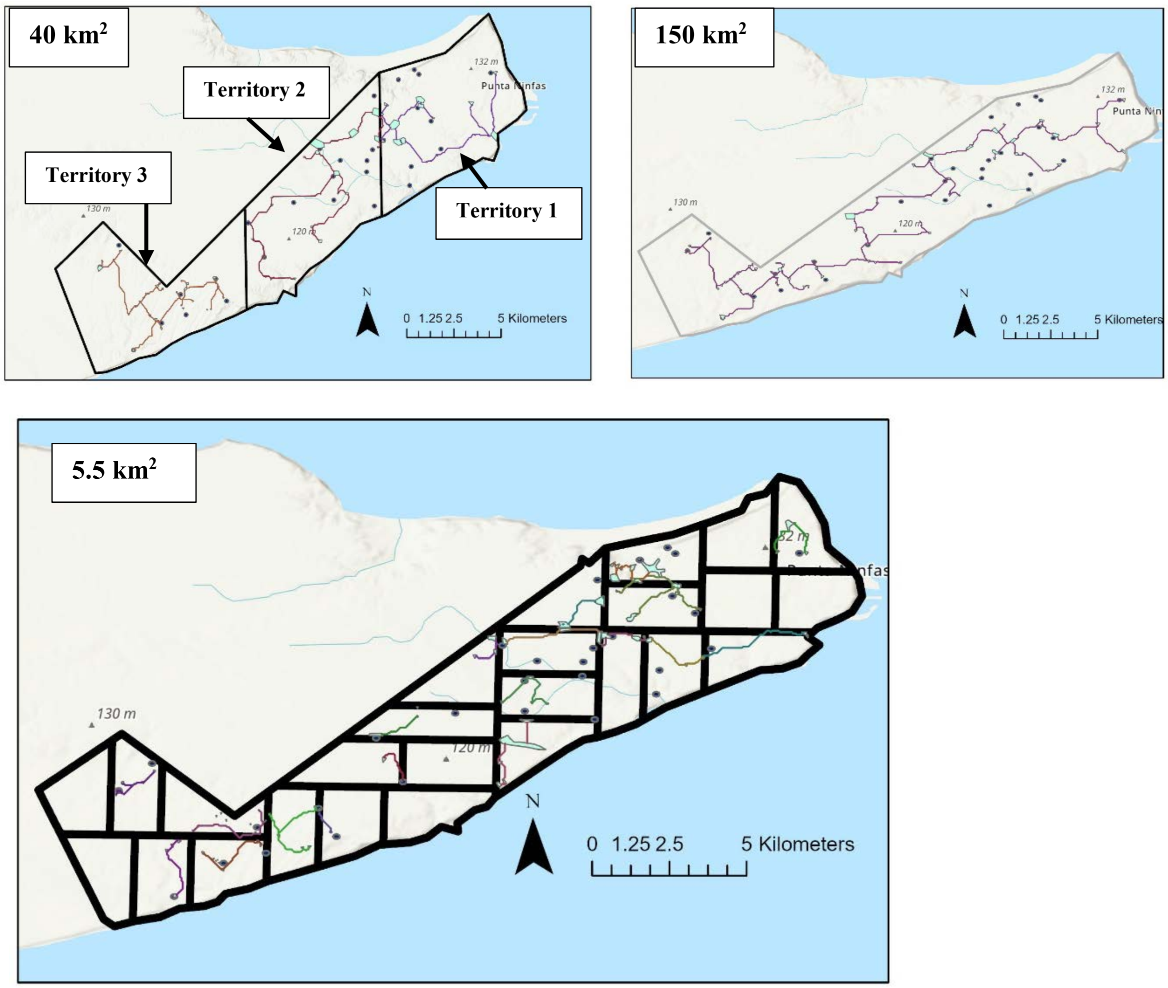


Figure 23. NHWL ratings results and Observed guanaco encounter frequencies by distance.

All highly rated sites are concentrated around long-term water sources in both null models, while observed results show that guanacos value distance away from human residence more than long-term water sources.

The LCP results are similarly inaccurate at predicting guanaco encounters, regardless of the three area scenarios (150 km^2, 40 km^2, and 5.5 km^2). This is largely due to the LCP approach itself, as it selects a single path on which it predicts all animal movement must be concentrated (Meek et al. 2014, Dickson et al. 2019). LCPs were routed close to multiple sites that had observed guanaco encounters within 100m in all territory size scenarios, and if the tool could determine several paths between points there would likely have been more matches in the results. A model based on circuit theory, which assumes animals have imperfect knowledge of the landscape and creates multiple routes between points, could have been a more accurate predictor of guanaco encounters within 100m (Disckson et al. 2019, Bishop-Taylor et al. 2015). Like the ratings model, LCPs also failed to reflect the high degree of difference between guanaco concentrations at different distances from human residence.

Figure 24. LCPs for all territory size scenarios.



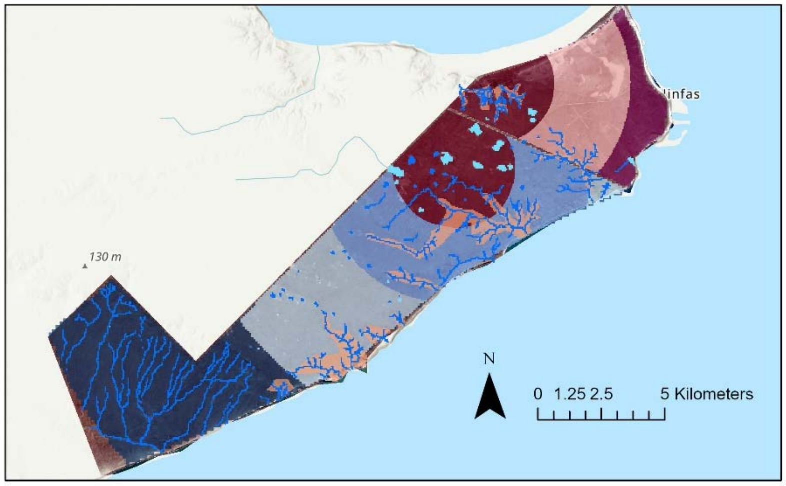
DISCUSSION

The inaccuracy of both models in predicting guanaco spatial patterns as observed by camera and in-person encounters shows that the parameters that inform these do not reflect guanaco behavior at El Pedral. Moreover, observed encounter results show that the expert and local knowledge and scientific literature that informed these parameters did not account for the high degree of avoidance of human residences displayed by guanacos. While other factors certainly contribute to guanaco spatial distributions at El Pedral, my results indicate that human presence (and the avoidance of areas of consistent human presence) is the factor that most affected guanaco encounters.

Both the site ratings and LCP models yield results based on weighted layers, the most important being the HWL. The inaccuracy of both models in predicting observed guanaco encounters, especially in terms of the spatial patterns of these encounters, indicates that the parameters for the models need to be improved to better reflect conditions at El Pedral. This means that the current values assigned to landscape features on the HWL do not accurately reflect the real value of these features to guanacos. Guanacos at El Pedral appear to avoid humans to a greater extent than the models reflect, and clearly give human residences more than the 200-meter buffer included in the HWL (Fig. 14).

Natural landscape features are not enough to explain the dramatic concentration of guanaco encounters in the area 10-16 km away from human residences. The site ratings based on the NHWL rated more sites in the northern and central part of the study site, closer to human residences, highly than in the southwestern part of the study site (Fig. 23). This is largely because most long-term water sources are concentrated in these areas (Fig. 25). Areas less than 10 km away from human residences also contain more pond or lake-like ephemeral water sources (Fig. 25). These depressions in the ground collect and hold water for longer periods of time than ephemeral streams (* Victor Fratto). If water were the most important factor affecting guanaco spatial distribution, photo encounters with guanacos would be a lot less concentrated. Vegetation quantity and quality was not assessed in this study beyond recording the height of the tallest vegetation at all camera sites. The range of vegetation height was 48-170 cm, but there was no apparent spatial pattern in terms of vegetation height (See Appendix).

Figure 25. Long-term water, ephemeral water, canyons and observed guanaco encounter frequency by distance away from human residences.



Similarly, predator presence is unlikely to affect guanaco spatial distribution at El Pedral as much as other factors. Local scientists and the *estancia* manager and owner all reported that there are no pumas in El Pedral or in other neighboring *estancias*, and my camera traps never encountered one. Two foxes were encountered, one within 5 km of a human residence and the other 10-16 km from a human residence (See Appendix). But guanacos are less vulnerable to foxes than they are to pumas, and are unlikely to alter their spatial distributions due to their presence alone (Novaro et al. 2009).

Competition over grazing and water has been cited as a primary factor shaping guanaco spatial distribution in Argentina. The presence of sheep is negatively correlated with guanaco presence at study cites in several papers (Baldi et al. 2016, Baldi et al. 2001, Moraga et al. 2014, Marino et al. 2008). However, many such studies over-rely on co-occurrence and density rates in conjunction with known dietary overlap to support the theory of competitive exclusion, failing to account for the direct effect of hunting and other human management practices associated with sheep-ranching on guanaco spatial preferences (Iranzo et al. 2013, Leblond et al. 2013). In Iranzo et al., guanacos at study sites in and around a protected area found that, at a fine scale, guanacos did not alter their habitat preferences at sites where sheep were present. In areas where they were not hunted or chased by humans, guanacos and sheep were able to exist in the same areas provided there was enough habitat heterogeneity (Iranzo et al. 2013). In other words, because both guanacos and sheep are generalists, it is possible for them to coexist in the same landscapes without excluding one another completely (Iranzo et al. 2013). My results at El Pedral support this hypothesis: photo encounters with sheep were second highest at 10-16km away from human residences (32.22%), where guanaco photo encounters were highest (93.21%) (Fig. 14 and 15). Meanwhile where the percentage of photo encounters with sheep was lowest (about 17.51%, 0-2km away), the percentage of photo encounters with guanacos was also its lowest (0%) (Fig. 14 and 15). Competition between sheep and guanacos for water also does not appear to explain guanaco spatial patterns at El Pedral: because most long-term and many of the longer-lasting ephemeral water sources are outside of the area with the highest rate of photo encounters with guanacos and the second highest rate of photo encounters with sheep. Based on photo encounters, there does not appear to be a strong correlation between sheep and guanaco presence at El Pedral.

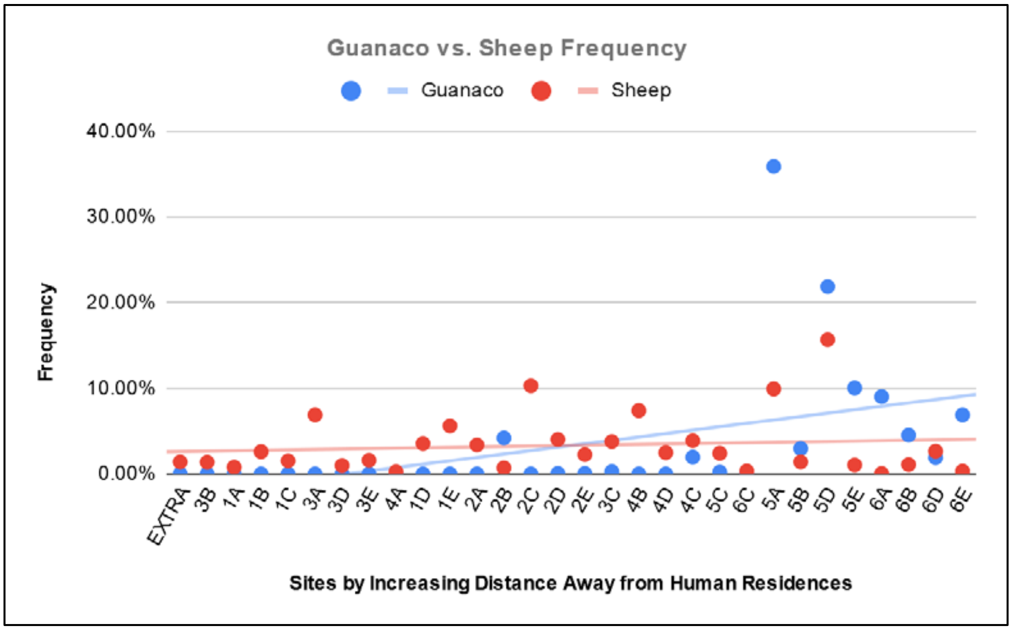


Figure 26. Guanaco and sheep photo encounter frequency in order of increasing distance away from human residences.

It is also worth noting that Iranzo et al.'s findings were based on a landscape with high habitat heterogeneity and biodiversity, which is not the case for all areas in Argentina inhabited by guanacos, particularly where livestock management practices have decreased habitat quality. Overgrazing has reduced vegetational quantity and diversity, decreased landscape heterogeneity, and increased erosion and subsequent desertification throughout Argentine Patagonia (Barri et al. 2016, Baldi et al. 2016, Moraga et al. 2014, Baldi et al. 2001, Cheli et al. 2016). Competition with sheep is likely dependent on the extent to which overgrazing and livestock-management practices have reduced quantity and variety of grazing resources, and should therefore not be applied universally as an explanatory variable for guanaco spatial distribution.

Furthermore, hunting directly affects spatial preferences of many species, including guanacos, and hunting of guanacos is widespread in Argentina (Mulero et al. 2016, Malo et al. 2011). Hunting, together with the expansion of sheep ranching and subsequent competition with livestock, is well-known to have caused the sharp decline in guanaco population numbers that nearly brought the species to extinction (Baldi et al. 2016). Guanacos are still widely referred to as “pests” or a “plague” by *gauchos* and even local governments. The government of the province of Santa Cruz (south of the study site) specifically used the term “pest” when referring to guanacos and the necessity of limiting their population, and the government of Chubut (where the study site is located) maintains that steps must be taken to limit guanaco numbers where they cause economic damage (Schroeder et al. 2014, Gobierno de Chubut). Language on what constitutes mitigation and what numbers guanacos have to reach before they become a problem is vague, and dietary overlap between sheep and guanacos is used to claim that competition leads directly to economic losses if guanaco numbers are not capped (Gobierno de Chubut). Neither of these plans includes rigorous, scientific local or state-level population counts to outline what a minimum viable population should be and at what population density guanacos cause economic losses (Schroeder et al. 2014, Gobierno de Chubut, * Victor Fratto).

Hunting in unprotected areas has been shown to affect guanaco spatial distributions. In areas of Patagonia where fracking exploration has created new roads poaching has increased and guanaco populations have dropped locally (St-Louise et al. 2014). Ungulates can become partially accustomed to low-trafficked roads – of which there are many in Patagonia (Mulero et al. 2016, Donadio et al. 2006). In many protected areas, guanacos can be seen easily from roads, and I saw many within 100m of roads on the nearby Peninsula Valdes (Malo et al. 2011). However, in areas where hunting occurs, guanacos are significantly more sensitive to vehicle presence (Donadio et al. 2006, Iranzo et al. 2013). In unprotected areas the distance a guanaco will tolerate between itself and a human or vehicle before fleeing is significantly higher than in protected areas (Iranzo et al. 2013). In other words, guanacos will allow humans to get closer in areas where they are not hunted. Malo et al. found that guanacos were more likely to be startled by vehicles on private, low-trafficked roads within ranch sites than on highly trafficked roads within a protected area (Malo et al. 2011). I did not differentiate between the more trafficked roads (Ruta 5, the lodge road and the roads leading from Ruta 5 to the *estancia* compound) and the private roads within the *estancia* but it is likely that guanacos avoid these more trafficked roads than the private roads. In Fig. 18, photo encounters of guanacos at sites along roads increased according to distance from residences. This shows that distance from residence is a bigger determinant of guanaco spatial preferences at El Pedral than the presence of roads alone, especially since human residences are clustered around more-trafficked roads.

These results of this study show that human presence is the variable that most affected guanaco spatial distribution at El Pedral. The results of both the site ratings and LCP models show that parameters informed by local and expert knowledge and scientific literature did not adequately represent the extent to which guanacos at El Pedral avoided areas of consistent human presence. The results of distance analysis show the disproportionately high concentration of guanacos in areas of the property that were farthest away from human residences, regardless of the location of long-term water sources, more reliable ephemeral water sources, roads, and the presence/concentration of sheep. Given that guanacos are guanacos are widely regarded as "pests" and thought to compete with sheep and cause economic losses to ranchers, it is highly probable that guanacos are hunted, chased and otherwise unwelcome on other ranches in Argentina (Schroeder et al. 2014, Gobierno de Chubut, Donadio et al. 2006, Baldi et al. 2001, St-Louise et al. 2014). This has implications for persistence of guanacos at local-levels, and for connectivity, genetic diversity and metapopulation dynamics at regional-levels.

CONCLUSION

Human activity shapes guanaco distributions not just at the ranch-level, but at regional levels. Landscape degradation brought on by overgrazing reduces habitat available to guanacos and human infrastructure in the form of fencing, roads, and residences, even in sparsely populated Patagonia, can greatly impact guanaco movements (Leblond et al. 2013). If accompanied by hunting, these features can fragment landscapes and reduce connectivity between guanaco populations, making populations more vulnerable to local extinctions and reducing genetic diversity (Bishop-Taylor et al. 2015, Mate et al. 2005). However, if hunting is reduced these features can become traversable, preserving connectivity between guanaco populations across ranches and Patagonia at large (Bishop-Taylor et al. 2015).

It is important to study the specific effect of human activity on guanaco behavior to better understand the dynamics that cause conflict between humans and guanacos. This study shows that humans clearly impact guanaco spatial patterns on one ranch in Argentina, and that this specific variable has an outsized impact on these patterns compared to other, traditional assumptions about guanacos. Because this is a pilot study, it will be important to conduct more in-depth analysis on this same question at other ranches to ensure El Pedral is not an anomaly. It is also important to include areas with and without sheep, as well as areas where hunting does and does not occur to further tease out the factors that most affect guanaco spatial preferences. Understanding this can not only help inform guanaco conservation efforts, but also guide further research on competition between sheep to understand whether competition between the two ungulates is exclusive and whether landscape degradation can actually create competition where niches might otherwise develop. Forming a better understanding of how humans affect guanaco spatial distributions can also inform research on the whole Patagonian ecosystem, from predator responses to spatial shifts to insect and vegetation regeneration in areas where guanacos are and are not present.

It is key that further research should involve humans and livestock. Without looking at how humans and livestock interact with wildlife, we will not understand the mechanisms that either endanger or enable the survival of various Patagonian species (Vargas et al. 2020). Most of Patagonia is made up of private land, so from a practical conservation perspective it is crucial to work with landowners to maintain connectivity and space for guanacos and other wildlife (Nabte et al. 2013). This is also important for people. Patagonia and its wildlife hold cultural value and can attract economic opportunities from tourism (Baldi et al. 2016). Guanacos are key to the health of the Patagonian ecosystem: they maintain vegetation health and diversity, support insect populations, and are a key source of food for apex and meso predators. These are ecosystem services on which Argentine *gauchos* and their livestock also depend. Scientists can help prove this link and work with local governments, landowners, and *gauchos* to promote conservation of guanacos and other Patagonian animals for the benefit of both wildlife and people.

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*Conversations with Miguel, caretaker of the *estancia* El Pedral. October-December 2019.

*Conversation with Pablo Garcia Borboroglu, renowned Argentine marine biologist and penguin conservation with the Global Penguin Society. October 2019.

*Conversation with Sebastian Stocker, owner of the *estancia* El Pedral. November 2019.

*Conversations with Victor Fratto, protected area and conservationist based in Puerto Madryn, Argentina. September-December 2019.

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APPENDIX

1. Camera sites: GIS-assigned, actual and distance between them.

	Random Site Assigned by QGIS	Actual Site Gaia	Distances between GIS to Actual
1-A	-42.96046, -64.37782	-42.96073, -64.37892	94.48 M
1-B	-42.96263, -64.37639	-42.96293, -64.37604	45.53 M
1-C	-42.97262, -64.40414	-42.97275, -64.40504	74.64 M
1-D	-42.97941, -64.37772	-42.97876, -64.37715	86.27 M
1-E	-42.98492, -64.36868	-42.98512, -64.36871	21.87 M
2-A	-43.00609, -64.38263	-43.00637, -64.38194	64.32 M
2-B	-42.99878, -64.36200	-42.99832, -64.36267	75.30 M
2-C	-43.02215, -64.43122	-43.02158, -64.43203	92.15 M
2-D	-43.01606, -64.38254	-43.01529, -64.38317	100.62 M
2-E	-43.02449, -64.40641	-43.02472, -64.40604	39.43 M
3-A	-42.99381, -64.39943	-42.99397, -64.40023	0.26 M
3-B	-42.99802, -64.40711	-42.99812, -64.40659	44.66 M
3-C	-43.01030, -64.43290	-43.01036, -64.43213	63.72 M
3-D	-43.00325, -64.41046	-43.00325, -64.41028	15.15 M
3-E	-43.00876, -64.40998	-43.00856, -64.41065	58.74 M
4-A	-43.00320, -64.42780	-43.00290, -64.42743	45.46 M
4-B	-42.99670, -64.44030	-42.99714, -64.44029	49.24 M
4-C	-43.04810, -64.47650	-43.04789, -64.47736	73.44 M
4-D	-43.02240, -64.45780	-43.02239, -64.45788	6.26 M
5-A	-43.05850, -64.50850	-43.05111, -64.58310	283.81 M
5-B	-43.06550, -64.53200	-43.04106, -64.57067	1,738.69 M
5-C	-43.059800, -64.557280	-43.03163, -64.48733	6,717.34 M
5-D	-43.06400, -64.55700	-43.05776, -64.50875	85.17 M
5-E	-43.05670, -64.57140	-43.06482, -64.53163	80.74 M
6-A	-43.06850, -64.50170	-43.07817, -64.54408	24.82 M
6-B	-43.07410, -64.52920	-43.09061, -64.56245	747.53 M
6-C	-42.96350, -64.32920	-42.96277, -64.32993	101.85 M
6-D	-43.07810, -64.54380	-43.06828, -64.50210	41.58 M
6-E	-43.08910, -64.57140	-43.07443, -64.52832	79.78 M
EXTRA SITE	-43.03160, -64.48740	-42.96530, -64.38925	10,877.38 M

2. GPS location of all in-person guanaco sightings and *bostaderos* found.

Guanaco Sightings	Bostaderos
-42.983373°, -64.368118°	-43.047320°, -64.477710°
-42.983786°, -64.366845°	-43.059860°, -64.526960°
-42.992441°, -64.403041°	-43.062470°, -64.528490°
-43.020243°, -64.472020°	-43.062270°, -64.528400°
-43.031691°, -64.486253°	-43.060040°, -64.527150°
-43.018535°, -64.440521°	-43.060040°, -64.527150°
-43.018548°, -64.429443°	-43.062780°, -64.528940°
-43.057103°, -64.476795°	-43.031370°, -64.488960°
-43.058100°, -64.473023°	-43.051900°, -64.582030°
-43.072498°, -64.514644°	-43.043940°, -64.569720°
-43.048060°, -64.574187°	-43.051360°, -64.583400°
-43.058143°, -64.508946°	-43.052400°, -64.584010°
-43.067168°, -64.530528°	-43.070010°, -64.531160°
-43.058209°, -64.458102°	-43.076550°, -64.548440°
-42.996979°, -64.403335°	-43.071390°, -64.530180°
-43.062115°, -64.543075°	-43.076660°, -64.548160°
-43.073673°, -64.565184°	-43.066750°, -64.504110°
-43.076928°, -64.546302°	-43.066670°, -64.532270°
-43.068026°, -64.523661°	-43.066470°, -64.504390°
-43.030530°, -64.489510°	-43.074330°, -64.551760°
-43.000997°, -64.450706°	-43.064540°, -64.532350°
-43.030522°, -64.486955°	-43.061610°, -64.507700°
-43.023540°, -64.471930°	-43.078030°, -64.545940°
-43.076420°, -64.547660°	-43.076730°, -64.547990°
-43.001168°, -64.365264°	-43.059660°, -64.508750°
-43.058450°, -64.530960°	-43.061970°, -64.507460°
-43.080730°, -64.544460°	-43.077240°, -64.546950°
-43.039420°, -64.484550°	-43.063620°, -64.534060°
-43.059570°, -64.544980°	-42.977090°, -64.342570°
-43.071430°, -64.563200°	-43.060620°, -64.546620°
-43.072050°, -64.512270°	-43.067810°, -64.557730°
-43.004106°, -64.371791°	-43.064400°, -64.553670°
-42.962730°, -64.327405°	-43.070030°, -64.560800°
-42.965141°, -64.389603°	-43.060700°, -64.546800°
	-43.064190°, -64.553370°
	-43.066100°, -64.555460°
	-43.090610°, -64.562450°

3. All ratings results.

Site	Observed Encounter Ratings	HWL Ratings	NHWL Ratings
1A	2	2	1
1B	2	2	2
1C	1	2	2
1D	2	2	5
1E	2	4	5
2A	2	3	3
2B	3	3	2
2C	2	4	5
2D	2	2	1
2E	2	4	2
3A	2	1	3
3B	2	2	4
3C	2	5	4
3D	2	5	5
3E	1	5	5
4A	1	5	3
4B	2	2	4
4C	3	3	5
4D	2	5	5
5A	5	4	5
5B	3	1	4
5C	2	3	3
5D	5	2	4
5E	5	2	3
6A	4	2	2
6B	3	1	1
6C	2	2	1
6D	3	3	2
6E	4	3	1
EXTRA SITE	2	2	2

4. All LCPs intersect encounter results.

	Least Cost Paths Intersect w/in 100 meters of camera sites:				
Site	26 5.5km2 areas	3 40 km2 areas	Whole 149.13 km2 area	In-Person Encounters w/in 100 m of site	Photo Encounters
1A	N	N	N	N	N
1B	N	N	N	N	N
1C	N	N	N	N	N
1D	N	N	N	N	N
1E	N	N	N	N	N
2A	N	N	N	N	N
2B	N	N	N	N	Y
2C	N	N	N	N	N
2D	N	N	N	N	Y
2E	N	N	N	N	Y
3A	Y	N	N	N	N
3B	N	N	N	N	N
3C	Y	Y	Y	N	Y
3D	N	N	N	N	N
3E	N	N	N	N	N
4A	N	N	N	N	N
4B	Y	Y	Y	N	N
4C	Y	Y	Y	N	Y
4D	N	N	N	N	N
5A	Y	Y	Y	N	Y
5B	N	N	N	N	Y
5C	N	Y	Y	Y	Y
5D	Y	Y	Y	Y	Y
5E	Y	N	Y	N	Y
6A	N	N	N	N	Y
6B	Y	Y	Y	N	Y
6C	N	N	Y	N	N
6D	N	N	N	N	Y
6E	N	N	N	N	Y
EXTRA	N	N	N	Y	N

5. All photo encounters (total and percentage).

	Guanacos	%	Sheep	%	Humans	%	Horses	%	Dogs	%	Other Wildlife	%	Predators	%
1A	0	0	87	0.8	0	0	0	0	0	0	16	3.19	0	0
1B	0	0	286	2.64	0	0	0	0	0	0	76	15.14	0	0
1C	0	0	169	1.56	2	5.71	0	0	0	0	11	2.19	0	0
1D	0	0	391	3.61	0	0	0	0	0	0	0	0	1	50
1E	0	0	617	5.7	4	11.43	0	0	0	0	12	2.39	0	0
2A	0	0	373	3.45	2	5.71	0	0	0	0	8	1.59	0	0
2B	75	4.21	78	0.72	0	0	0	0	1	25	2	0.4	0	0
2C	0	0	1131	10.45	0	0	7	0.53	0	0	1	0.2	0	0
2D	1	0.06	443	4.09	1	2.86	0	0	0	0	0	0	0	0
2E	1	0.06	249	2.3	0	0	0	0	0	0	17	3.39	0	0
3A	0	0	758	7.01	0	0	173	13.22	0	0	16	3.19	0	0
3B	0	0	152	1.4	1	2.86	16	1.22	0	0	1	0.2	0	0
3C	5	0.28	416	3.85	12	34.29	699	53.4	0	0	15	2.99	0	0
3D	0	0	109	1.01	0	0	0	0	0	0	5	1	0	0
3E	0	0	176	1.63	0	0	140	10.7	0	0	4	0.8	0	0
4A	0	0	29	0.27	0	0	0	0	0	0	0	0	0	0
4B	0	0	813	7.51	1	2.86	17	1.3	0	0	68	13.55	0	0
4C	35	1.96	428	3.96	0	0	0	0	0	0	66	13.15	0	0
4D	0	0	274	2.53	0	0	0	0	0	0	39	7.77	0	0
5A	640	35.91	1090	10.07	0	0	164	12.53	0	0	121	24.10	0	0
5B	53	2.97	155	1.43	0	0	17	1.3	0	0	5	1	0	0
5C	4	0.22	266	2.46	0	0	0	0	0	0	7	1.39	0	0
5D	390	21.89	1721	15.91	4	11.43	71	5.42	0	0	0	0	1	50
5E	179	10.04	116	1.07	0	0	0	0	0	0	3	0.6	0	0
6A	161	9.03	5	0.05	0	0	0	0	0	0	0	0	0	0

6B	81	4.55	121	1.12	0	0	0	0	0	0	0	0	0	0
6C	0	0	38	0.35	2	5.71	0	0	0	0	2	0.4	0	0
6D	34	1.91	292	2.7	0	0	0	0	0	0	0	0	0	0
6E	123	6.9	36	0.33	6	17.14	5	0.38	0	0	0	0	0	0
EXTRA SITE	0	0	155	1.43	0	0	0	0	3	75	7	1.39	0	0
TOTAL EACH CATEGORY	1782	-	10819	-	35	-	1309	-	4	-	502	-	2	-

6. All site characteristics.

	Site Characteristics			Features					Water Features					Human Features	
Site Name	**Road**	**Animal Trail**	**Detection Distance (paces)**	**Tallest Vegetation (cm)**	**Grassland/Low Bushes**	**Sand Dune**	**Canyon**	**Riparian (Water's Edge)**	**Natural Lagoon**	**Tajamar**	**Molino**	**Puddle**	**Any**	**Fence**	**Unpaved Road**
1A	0	1	12	126	1	0	0	0	0	0	0	0	0	0	0
1B	0	1	12	89	1	0	0	0	0	0	0	0	0	0	0
1C	1	1	14	165	1	0	0	0	0	0	0	0	0	0	1
1D	1	1	14	61	1	0	0	0	0	1	0	0	1	0	1
1E	1	1	12	120	1	0	0	0	0	0	0	0	0	0	1
2A	0	1	13	79	1	0	0	0	0	0	0	0	0	0	1
2B	0	1	14	64	1	0	0	0	0	0	0	0	0	0	0
2C	0	1	12	64	1	0	0	0	0	0	0	0	0	1	1
2D	1	1	13	108	1	0	1	0	0	0	0	1	1	0	1
2E	0	1	12	63	1	0	0	0	0	0	0	0	0	0	0
3A	1	1	11	52	1	0	0	1	0	1	0	0	1	0	1
3B	1	1	13	67	1	0	0	0	0	1	0	0	1	1	1
3C	0	1	15	78	1	0	0	0	1	0	0	0	1	0	0
3D	0	1	17	68	1	0	0	0	0	0	0	0	0	0	0
3E	0	1	15	80	1	0	0	0	0	0	0	0	0	0	0
4A	0	1	16	153	1	0	0	0	0	0	0	0	0	0	0
4B	0	1	15	48	1	0	0	1	1	0	0	0	1	1	1
4C	0	1	19	85	1	0	0	0	0	0	0	0	0	0	0
4D	0	1	13	71	1	0	0	0	0	0	0	0	0	0	0
4E	0	1	13	82	1	0	0	0	0	0	0	0	0	0	0
5A	1	1	15	82	1	0	0	1	0	1	0	0	1	0	1
5B	1	1	14	157	1	0	0	0	0	0	0	0	0	1	1
5C	0	1	13	82	1	0	0	0	0	0	0	0	0	0	0
5D	1	1	16	65	1	0	0	0	0	1	0	0	1	0	1
5E	0	1	19	116	1	0	0	0	0	0	0	0	0	0	0
6A	0	1	21	111	1	0	0	0	0	0	0	0	0	0	0
6B	0	1	10	130	1	0	0	0	0	0	0	0	0	0	0
6C	0	1	14	119	1	1	0	0	0	0	0	0	0	0	0
6D	1	1	15	113	1	0	0	0	0	0	0	0	0	0	1
6E	0	1	20	73	1	0	1	0	0	0	0	0	0	0	0
Extra Site	0	1	25	170	1	0	0	0	0	0	1	0	1	1	1

7. All animal signs at sites, per visit.

	Guanacos				Wildlife								Domestic							Humans		
Site	Track	Scat	Present	# of individuals seen	Track	Of What	Scat	Of What	Present	What	Carcasses/Bones	What	Track	Of What	Scat	Of What	Present	What	Carcasses/Bones	Track (Vehicle)	Garbage	Vehicle Traffic
1A 1	0	0	0	0	1	Choique	1	Choique	1	Choique	0	0	1	Sheep	1	Sheep Horse	1	Sheep	0	0	0	0
1A 2	0	0	0	0	0	0	1	Choique	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
1A 3	0	0	0	0	0	0	1	Choique	0	0	0	0	1	Sheep Horse	1	Sheep	0	0	0	0	0	0
1B 1	0	0	0	0	1	Choique	1	Choique	1	Choique	0	0	1	Sheep Horse	1	Sheep Horse	0	0	Sheep Carcass	0	0	1
1B 2	0	0	0	0	0	0	1	Choique	0	0	0	0	1	Sheep Horse	1	Sheep Horse	0	0	Sheep Carcass	0	0	0
1B 3	0	0	0	0	0	0	1	Choique	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	Sheep Carcass	0	0	0
1C 1	0	0	0	0	0	0	0	0	1	Martineta Egg	0	0	1	Sheep Horse	1	Sheep Horse	0	0	0	1	0	1
1C 2	0	0	0	0	0	0	0	0	1	Martineta Egg	0	0	1	Sheep Horse	1	Sheep	0	0	0	1	0	1
1C 3	0	0	0	0	0	0	1	Liebre	1	Martineta Egg	0	0	1	Sheep	1	Sheep	0	0	0	1	0	0
1D 1	0	0	0	0	1	Flamingos Ducks	0	0	1	Flamingos Ducks	0	0	1	Sheep Horse	1	Sheep Horse	1	Sheep	Sheep Carcass	1	0	0
1D 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	1	Sheep	Sheep Carcass	1	0	0
1D 3	0	0	0	0	0	0	0	0	1	2 Flamingos	0	0	1	Sheep	1	Sheep	1	Sheep	Sheep Carcass	0	0	0
1E 1	0	0	1	6	0	0	0	0	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Sheep	Sheep Bones	1	0	0
1E 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	Sheep Bones	1	0	0

1E 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	Sheep Bones	1	0	0
1E 3	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	Sheep Bones	1	0	0
2A 1	0	0	0	0	0	0	1	Choique Liebre	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2A 2	0	0	0	0	0	0	1	Liebre	1	Eggshell	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2A 3	0	0	0	0	0	0	1	Choique Liebre	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2B 1	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2B 2	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2B 3	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
2C 1	0	0	0	0	0	0	0	0	0	0	0	0	1	Horse	1	Sheep Horse	0	0	0	0	0	0
2C 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
2C 3	0	0	0	0	0	0	1	Choique Liebre	0	0	0	0	1	Sheep Horse	1	Sheep Horse	0	0	0	0	0	0
2D 1	1	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	1	0	0
2D 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	1	0	0
2D 3	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	1	0	0
2E 1	0	0	0	0	0	0	0	0	0	0	0	0	1	Horse	1	Sheep Horse	0	0	0	0	0	0
2E 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep Horse	0	0	0	0	0	0
2E 3	0	0	0	0	0	0	1	Choique	0	0	0	0	0	0	1	Sheep Horse	0	0	0	0	0	0
3A 2	0	0	1	1	0	0	1	Liebre	0	0	1	Dead Peludo/ Canine Skull	1	Sheep Horse	1	Sheep Horse	0	0	Dead Sheep	1	0	0

3A 3	0	0	0	0	0	0	1	Liebre	0	0	1	Dead Peludo/ Canine Skull	1	Sheep Horse	1	Sheep Horse	0	0	Dead Sheep	1	0	0
3B 1	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep Horse	1	Sheep Horse	0	0	0	1	1	0
3B 2	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	1	0	0
3B 3	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Dog Horse Sheep	0	1	0	0
3C 1	0	0	0	0	0	0	0	0	0	0	0	0	1	Horse	1	Sheep Horse	0	0	0	0	0	0
3C 2	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Horse	0	0	0	0
3C 3	0	0	1	4	0	0	1	Liebre	0	0	0	0	1	Horse	1	Sheep Horse	1	Sheep	0	0	0	0
3D 1	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep Horse	1	Sheep Horse	0	0	0	0	0	0
3D 2	0	0	0	0	0	0	1	Liebre	0	0	0	0	0	0	1	Sheep Horse	0	0	0	0	0	0
3D 3	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
3E 1	0	0	0	0	0	0	0	0	0	0	1	Unidentifiable bones	1	Sheep Horse	1	Sheep Horse	0	0	0	1	0	0
3E 2	0	0	0	0	0	0	1	Choique	0	0	1	Unidentifiable bones	1	Horse	1	Sheep Horse	0	0	0	0	0	0
3E 3	0	0	0	0	0	0	1	Liebre	0	0	1	Unidentifiable bones	0	0	1	Sheep Horse	0	0	0	0	0	0
4A 1	0	0	0	0	0	0	1	Choique Liebre	1	Lizard Choique Eggshell	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
4A 3	0	0	0	0	0	0	1	Liebre	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0

4B 1	0	0	0	0	0	0	1	Liebre Choique Mara	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Sheep	0	0	0	0
4B 2	0	1	0	0	0	0	1	Liebre Mara	0	0	0	0	1	Sheep Horse	1	Sheep	0	0	0	1	0	0
4B 3	0	0	0	0	0	0	1	Liebre Mara	0	0	0	0	1	Sheep Horse	1	Sheep	0	0	0	1	0	0
4C 1	0	1	0	0	0	0	1	Choique Mara	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
4C 2	0	0	0	0	0	0	1	Choique Mara Liebre	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
4C 3	0	0	0	0	0	0	1	Choique Mara	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
4D 1	0	0	0	0	0	0	1	Liebre	1	Liebre	0	0	0	0	1	Sheep	0	0	0	0	0	0
4D 2	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep Horse	1	Sheep Horse	0	0	0	0	0	0
4D 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep Horse	0	0	0	0	0	0
4E 1	0	0	0	0	1	Liebre	1	Liebre	0	0	0	0	0	0	1	Sheep Horse	1	Sheep	0	0	0	0
4E 2	0	0	1	4	0	0	1	Liebre	0	0	0	0	0	0	0	0	1	Sheep	0	0	0	0
4E 3	0	1	0	0	0	0	1	Liebre	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
5A 1	0	0	1	35	0	0	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0	0	0
5A 3	0	0	0	0	0	0	1	Choique	0	0	0	0	1	Sheep	0	0	0	0	0	0	0	0
5B 1	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
5B 3	1	1	1	6	0	0	1	Choique	1	Martineta	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
5C 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
5C 3	0	1	0	0	0	0	1	Choique Liebre	0	0	0	0	1	Sheep Horse	1	Sheep	0	0	0	0	0	0

5D 1	0	1	1	1	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
5D 3	0	1	1	20	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	1	Sheep	0	0	0	0
5E 1	1	1	1	15	0	0	0	0	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Sheep	0	0	0	0
5E 3	0	1	1	10	0	0	0	0	0	0	0	0	0	0	1	Horse	0	0	0	0	0	0
6A 1	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6A 3	0	1	1	5	0	0	0	0	0	0	0	0	0	0	1	Sheep Horse	0	0	0	0	0	0
6B 1	1	1	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	0	0	0	0	0	0
6B 3	1	1	0	0	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	1	0
6C 1	0	0	0	0	1	Pawprints Liebre Mara	1	Canine/ Feline Choique Liebre	1	2 Mara	0	0	1	Sheep	1	Sheep	0	0	0	0	0	1
6C 2	0	0	1	4	0	0	1	Choique Liebre	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
6C 3	0	0	0	0	0	0	1	Choique Liebre	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
6D 1	1	1	1	10	0	0	0	0	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
6D 3	1	1	0	0	0	0	1	Liebre	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
6E 1	0	0	1	6	0	0	0	0	0	0	0	0	1	Sheep	1	Sheep	1	Sheep	0	0	0	0
6E 3	0	1	0	0	0	0	1	Liebre	0	0	0	0	0	0	1	Sheep	0	0	0	0	0	0
Extra Site 1	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep Horse	1	Sheep Horse	1	Sheep	0	0	0	0
Extra Site 2	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep Horse	0	0	0	0	0	0
Extra Site 3	0	0	0	0	0	0	1	Liebre	0	0	0	0	1	Sheep	1	Sheep Horse	1	Sheep Horse	0	0	0	0